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RESIDUAL RADIATION from a VERY-LOW-YIELD BURST (U)

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WT-1678

OPERATION HARDTACK — PROJECT 2.10

RESIDUAL RADIATION from a VERY-LOW-YIELD BURST (U)

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FOREWORD

This report presents the final results of one of the projects participating in the military-effect programs of Operation Hardtack. Overall information about this and the other military-effect projects can be obtained from ITR–1660, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, type, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussions of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

ABSTRACT

This project participated during Shots Quince and Fig to determine the radiation intensities of contaminated areas resulting from a very-low-yield, surface nuclear detonation.

This objective was accomplished by: (1) monitoring the crater and lip shortly after detonation, (2) performing helicopter-to-ground surveys at preselected points, (3) making a number of ground surveys during and after sample collection, (4) determining the gross gamma decay of the residual radiation from collected fallout samples, and (5) documenting the alpha contamination.

The area at ground zero for Shots Quince and Fig at Eniwetok Proving Ground was prepared by substituting soil from the Nevada Test Site (NTS) for the coral soil within the expected crater volume and over areas that were expected to contribute debris to the cloud.

Shot Quince did not go nuclear and created only alpha contamination. Decontamination of a 30-degree sector extending 300 feet downwind from ground zero would have been necessary. The highest alpha air concentration was less than 2 percent of the 1-hour emergency exposure of 2×10^{-8} $\mu c/cm^3$.

The radiation intensities at the lip and crater of Shot Fig were above 10,000 r/hr at H+26 minutes, a level that would have necessitated avoidance of these areas by troops.

The areas contaminated to levels of 200 r/hr were approximately the same size as predicted by the present scaling laws. However, this is probably only true if a weapon similar to the Fig device is fired under identical conditions, because the activity induced by Na^{24} in the fallout was a significant contributor to the total dose rate.

The fallout consisted of NTS soil and coral particles and the size fractions above 420 microns contained most of the activity. Several types of particles were observed. However, fused silicate particles in the 420-to-840-micron fraction contributed 95 percent of the total activity, although they were only 9 percent of the total weight.

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Chapter 1
INTRODUCTION

1.1 OBJECTIVE

The objective was to determine the radiation intensities of contaminated areas resulting from a very-low-yield (fractional-kiloton), surface nuclear detonation.

This objective was accomplished by: (1) monitoring the crater and lip shortly after detonation, (2) performing helicopter-to-ground surveys at preselected points, (3) making a number of ground surveys during and after sample collection, (4) determining the gross gamma decay of the residual radiation from collected fallout samples, and (5) documenting the alpha contamination.

1.2 BACKGROUND AND THEORY

1.2.1 Definition of Surface Burst. A surface burst is defined as one that occurs on or above the surface of land or water and whose fireball (at maximum brilliance) touches the surface.

1.2.2 Fallout Contamination. The basic fallout phenomena associated with a low-fission-yield surface burst are expected to be essentially the same as those for a high-fission-yield surface burst. For a low fission yield, however, the quantity of fission products will be smaller and the area that will be contaminated will be proportionately smaller.

Nature of Contamination. In a surface detonation the fireball incorporates some of the surface material, which becomes contaminated with the radioactive products of the nuclear explosion and is then precipitated to the earth as fallout contamination. The fallout radioactive contaminants will consist of: (1) fission products, (2) neutron-capture products formed in the device materials, and (3) neutron-capture products formed in the nearby land or water. The first of these types predominates over the others.

The fraction of the total radioactive products of the nuclear explosion that appears in the local fallout depends upon the extent to which the fireball touches the surface. Thus, the proportion of the available activity increases as the height of burst decreases and more of the fireball comes into contact with the earth. Where the device is actually on the surface when it explodes, at least 50 percent of the total residual radioactivity will be deposited on the ground within the local fallout area. In a surface burst, large amounts of earth, dust, and debris are taken up into the fireball in the solid, liquid, and gaseous states. This material becomes intimately mixed with the fission and activation products. As a result, there is formed upon cooling a tremendous number of small particles contaminated to some distance below their surfaces with radioactive matter. In addition, there are considerable quantities of particles, ranging from large lumps to fine dust, that are surface coated with fission products.

Shape of Contamination Pattern. Provided the wind is not excessive, the large particulate material, as it falls, will form a roughly circular pattern around ground zero. The center of this circular pattern, called the "ground-zero circle," will usually be displaced somewhat from ground zero by the wind. Most of the contaminated material, forming the ground-zero circle, descends within a short time. The smaller particles in the atomic column and cloud are, however, carried upward to a considerable height and may spread out some distance before

they begin to descend. The time taken to reach the earth and the horizontal distance traveled will depend upon the height reached before they begin to fall, the size of tne particles, and upon the wind pattern. As a general rule, it is to be expected that the fallout in the course of time will form a kind of elongated (cigar-shaped) pattern of contamination. The shape and dimensions will be determined by the wind velocities and directions at all altitudes between the ground and the top of the atomic cloud.

1.2.3 Military Significance. Fallout contamination from very-low-yield weapons must be considered in both offensive and defensive planning for ground warfare. Knowledge of the extent and location of the radioactive areas resulting from the surface detonation of very-low-yield weapons is required in order to more-effectively exploit the offensive use of these weapons and to prepare the necessary countermeasures for a defense against the use of such weapons.

1.2.4 Previous Test Results. Most of the information that has been obtained with respect to fallout contamination deals with detonations of very-high-yield weapons in the megaton range. Only one low-yield surface detonation has been documented for fallout. This was the 1.2-kt surface shot during Operation Jangle (References 1 through 14). After this shot, a fallout intensity of 100 r/hr at H+1 hour was found as far as 4,000 yards downwind and 500 yards crosswind. The downwind radiation pattern extended well beyond the region of blast and thermal damage. Measurements of the quantity of fallout material, time of arrival, and rate of arrival were obtained. The specific activity increased with distance downwind, up to a maximum, while the total activity at a given station decreased.

Fallout was collected at various distances from ground zero, and analyzed for radiochemical and radiophysical properties. Considerable fractionation was observed in the fallout, and a dependence of the radiochemical composition upon the particle size was indicated. It was found that almost all the activity was associated with particles larger than 100 microns in diameter. Results also showed that activity was distributed uniformly in most of the particles. Active particles ranged from colorless to jet black, with the greater activity usually associated with the darker colors.

Both field gamma-decay measurements and laboratory beta-decay measurements were made. It was found that the normal fission-product decay rate $t^{-1.2}$ was applicable except for the period between 48 hours and 2 weeks. During this period the influence of Np^{239} gave a slightly different decay rate. The maximum effect of the Np^{239} was noted at about 5 days.

Most of the radioactivity at the crater lip was concentrated on the surface, with a rapid falloff of specific activity with depth. At a depth of 1 inch, the activity was less than 5 percent of the surface activity, and some of the subsurface activity may have been due to unavoidable contamination arising from the method of core sampling. The available data provide no sound basis for scaling the fallout patterns to very-low-yield detonations.

Chapter 2
PROCEDURE

2.1 SHOT PARTICIPATION

The project was originally scheduled for participation only during Shot Quince, a surface burst of a very-low-yield device on Site Yvonne of the Eniwetok Proving Ground (EPG). Because this shot did not go nuclear, the project then participated in Shot Fig at the same ground zero and with the same instrumentation array. The station layout is presented in Figure 2.1.

For both shots, a conically shaped excavation, 30 feet in diameter and 8 feet deep, which was expected to contain the crater volume, was filled with soil from Area 10 at Nevada Test Site (NTS) (Reference 15). This was done in order to minimize confusion in interpreting the fallout results, because most of the fallout data for yields below the megaton range has come from bursts over NTS soil.

2.2 SUMMARY OF OPERATIONS

Gamma dose-rate readings 3 feet above the ground of the complete available land area were determined with the helicopter-to-ground aerial-survey instrument and with AN/PDR-39 survey meters. The data should be accurate to ±20 percent.

It was intended to pull the probe of a Jordan survey meter toward and into the crater to determine the gamma radiation existing in and around the crater.

The amount of alpha contamination was obtained by monitoring concrete slabs placed at various locations and measuring the filter paper from the air samplers. The readings from the concrete surface were reduced to microcuries per square centimeter and those from the air samples to disintegrations per minute per cubic meter. The results are estimated to be accurate to ±30 percent.

Fallout samples were obtained by means of open-close and open gross-fallout collectors. These samples were weighed and the amount of fallout per unit area and the relative activity per unit weight calculated. Three of the fallout samples were used to determine the gross gamma dose decay rates and activity of the size-fractionated samples. Gamma spectra and radiochemical analyses were performed, and the fallout particles were classified according to physical appearance.

2.3 INSTRUMENTATION

Instrumentation consisted of the helicopter-to-ground survey instrument, fallout collectors, crater-survey instrument, air samplers, concrete slabs, gas-flow proportional alpha counter, AN/PDR-39 survey meters, and aerial-survey markers.

2.3.1 Helicopter-to-Ground Survey Instrument. The aerial-survey equipment is illustrated in Figure 2.2. It consisted of a radiation detector mounted in a probe that could be lowered from a helicopter by means of a special cable and a powered reel to take readings 3 feet above the ground. The instrument and its use is described in detail in Reference 16.

The instrument was calibrated before and after each use with a 500-curie Co^{60} source, as described in Appendix A.

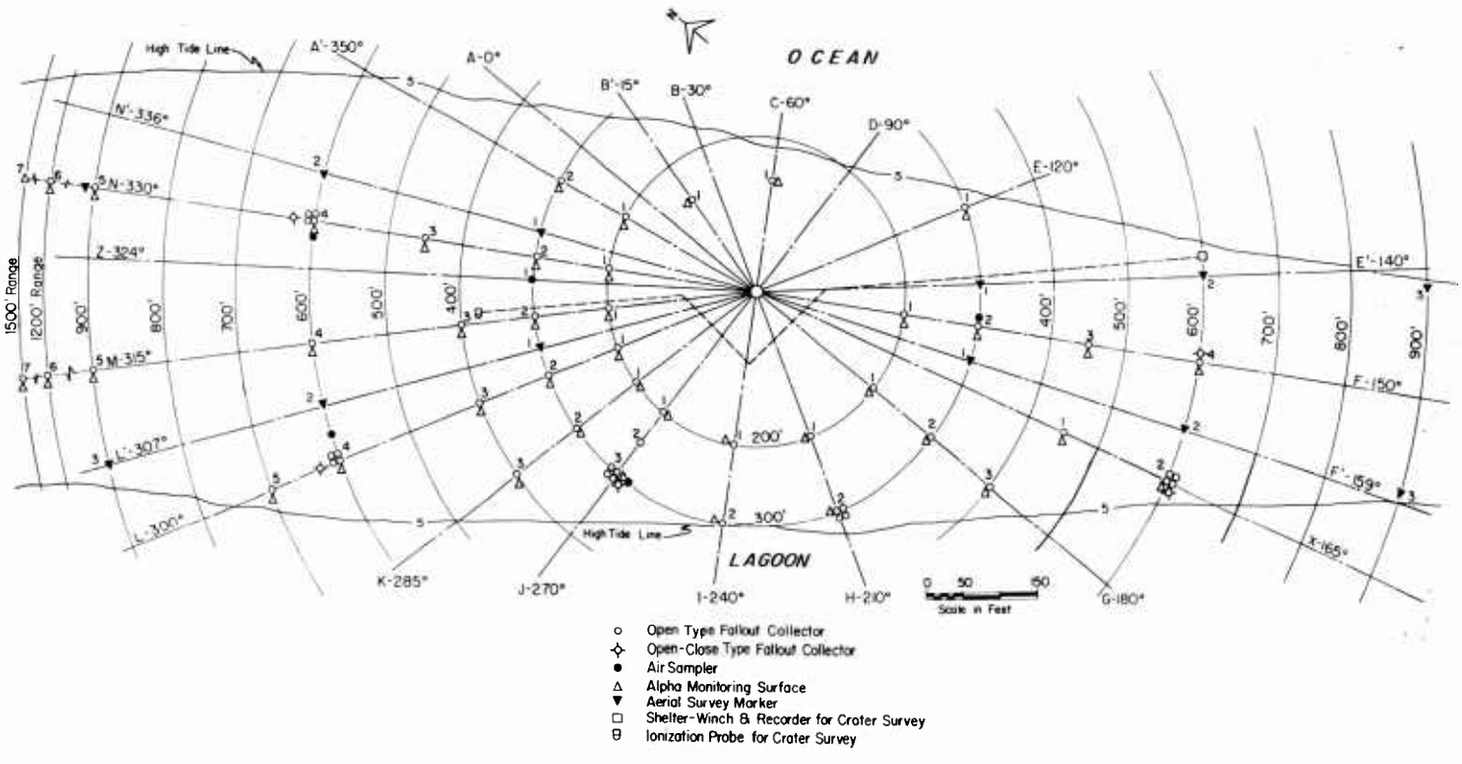


Figure 2.1 Station layout, Site Yvonne.

2.3.2 Fallout Collectors. Two types were used: open-close and open gross-fallout. The open-close collectors had a metal support framework and a conical liner with a door covering the opening. The liner had an opening approximately 2 feet in diameter at the top. In the bottom of the cone was a stainless-steel filter, 4 inches in diameter, which covered a small

Figure 2.2 Aerial-survey equipment.

hole leading to a polyethylene bottle. Figure 2.3 shows the collector with the door open, and Figure 2.4 shows it with the door closed. The door opened and closed with a sliding action. It had a notched strip rack on its top and was driven by a 24-volt dc motor through a chain-and-gear-drive system. The control system was activated by the closing of a relay in an Edgerton,

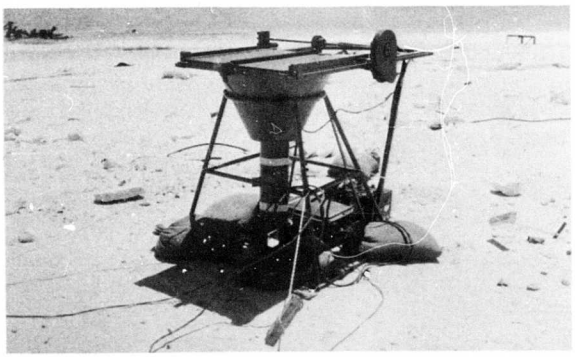


Figure 2.3 Open-close collector with door open.

Germeshausen and Grier, Inc. (EG&G) hard-wire signal system, 1 second before the detonation. During recovery, the door was opened manually, and a cover was put on the cone liner. After the hose to the polyethylene bottle was disconnected, the cone liner and the bottle were removed from the gross collector and transported to the laboratory area.

The open gross-fallout collectors were polyethylene buckets 16 inches deep, each with a 13-inch-diameter opening and a polyethylene cover to prevent spilling of the fallout during transport to the laboratory area. Figure 2.5 shows an open-type-collector installation. The covers were removed manually a few hours before the shot and replaced during recovery.

2.3.3 Crater-Survey Instrument. The crater-survey instrument was a Jordan survey meter modified to record the radiation intensity on a Brown recorder. The probe, instead of being fastened to a tripod, was shock-mounted inside a fiberglass cylinder for protection when pulled

into the crater. The equipment is shown in Figure 2.6. The winch and the recorder were covered by a wooden shed, which was surrounded by sandbags. Figure 2.7 shows the wooden shed and the radiation probe.

2.3.4 Air Samplers. Five air samplers were used to determine the alpha concentration in the air. These samplers used 24-volt dc motors manufactured by Electrolux Corporation. The

Figure 2.4 Open-close collector with door closed.

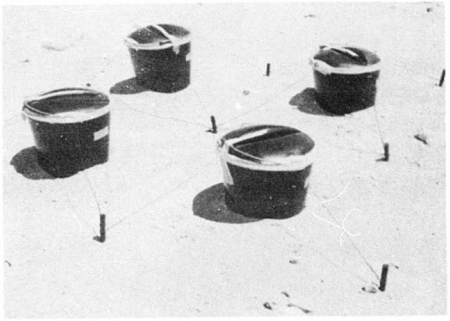


Figure 2.5 Open-type fallout collector installation. (Covers were removed a few hours before the shot.

motors ran at approximately 10,300 rpm, and the average air sampling rate for five samples was approximately 5 ft^3/min through a No. 6 Chemical Corps filter paper. The sampling area was 15.5 in^2. A typical field setup of the air samplers is shown in Figure 2.8.

2.3.5 Alpha Counters. Two gas-flow proportional alpha counters PAC-3G (Eberline Instrument Division of Reynolds Electrical and Engineering Co., Santa Fe, New Mexico) were used for surface monitoring. The instrument consists of a gas-flow proportional chamber, a transistorized pulse amplifier, and a one-shot multivibrator window of 0.85 mg/cm^2 density covering

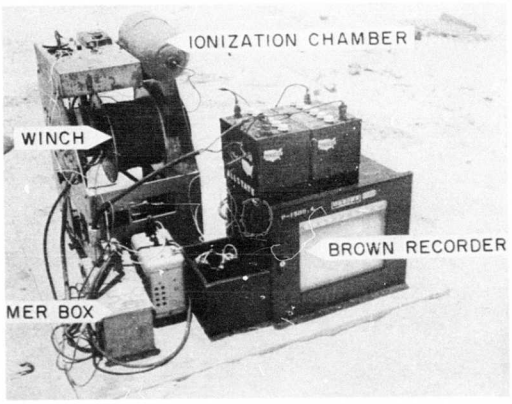


Figure 2.6 Crater-survey equipment.

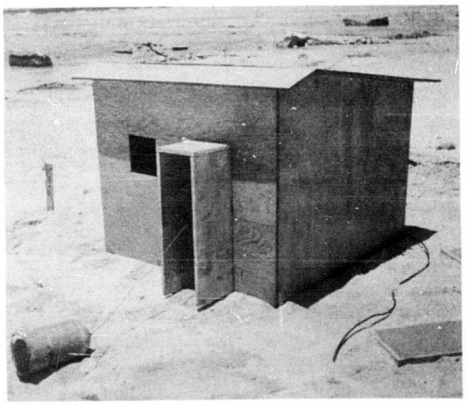


Figure 2.7 Housing for crater-survey winch and recorder.

an area of 61 cm^2. Each instrument housing was encased in a plastic bag. The cable and probe handle were covered by masking tape without interfering with the sensitive probe area. These precautions were used to prevent instrument contamination.

The maximum meter reading of the survey instrument was 100,000 counts/min. When the instrument went off-scale, only a fraction of the sensitive surface was used to take readings, and an appropriate multiplying factor was employed to correct to equivalent 61 cm^2 measurements.

The primary alpha standards used were two disks coated with uranium oxide. The smaller source disintegrated at the rate of 3,224 dis/min and the larger at 45,577 dis/min in a 50-percent geometry. The probe could "see" only 86 percent of the smaller source and 80 percent of the larger source. Therefore, the sources were actually rated at 2,770 and 36,460 dis/min.

Secondary standards of uranium screwed into the inside of the instrument case were used in the field for quick instrument checks. These sources were rated at 1,750 and 2,500 dis/min.

The instruments were calibrated at the beginning of each day and at the end of each survey.

2.3.6 Alpha-Monitoring Surfaces. A broom-finish concrete surface, representative of a typical urban sidewalk, was chosen as the standard surface to be monitored. Forty-four of these surfaces, 10 by 10 by 2 inches, were used. Figure 2.9 shows one of these concrete slabs in place.

Figure 2.8 Field setup of air sampler.

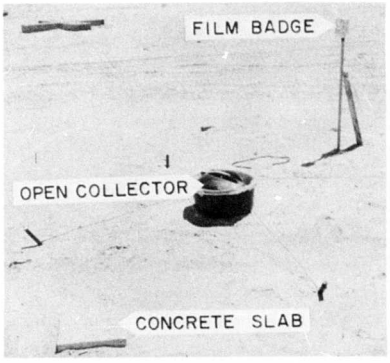


Figure 2.9 Concrete slab for alpha monitoring.

2.3.7 Gamma-Survey Meters. All gamma ground surveys were performed with the standard AN/PDR-39 survey meter. The instrument consists of an ionization chamber and measures the intensity of gamma radiation from 0 to 50,000 mr/hr on five scale ranges. It has an overall accuracy of ±15 percent.

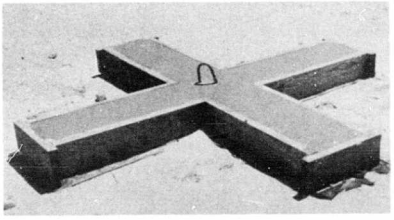


Figure 2.10 Aerial-survey marker.

2.3.8 Aerial-Survey Markers. The aerial-survey markers consisted of concrete crosses with each arm of the cross 3 feet long, 10 inches wide, and 6 inches thick. Figure 2.10 shows an aerial-survey marker in place.

2.4 TECHNIQUES

2.4.1 Gamma Ground Survey. The fallout-collector stations were used for ground-survey points. The early recovery parties of Projects 2.4, 2.9, 2.10, and 2.11 obtained gamma dose-rate readings during the recovery operations and at later times. These survey measurements were made while the meters were held approximately 3 feet above ground and away from the body.

2.4.2 Aerial Survey. At H+1 minute, an H-21 helicopter with Chemical Corps aerial survey equipment and two project personnel aboard departed Site Elmer for Site Yvonne and measured

the intensity of the ground residual radiation beginning at H+20 minutes, by the helicopter-to-ground survey technique at the established aerial-survey markers. The markers were approximately 300, 600, and 900 feet from ground zero along the four legs of the grid system. The locations of the twelve markers are given in Appendix A, Table A.1. These markers served only as guides, but it was usually possible to place the probe within 10 feet of them. In addition to those readings obtained at the established survey points, measurements were obtained at easily recognized landmarks on the island. After completion of the readings, the helicopter returned to Site Elmer. The readings were taken again at the same points at H+17 and H+24 hours.

2.4.3 Crater Survey. It was planned to take readings in and around the crater by remotely pulling the probe of a Jordan survey meter toward and into the crater. The probe was placed on the ground 375 feet from ground zero on an azimuth of 317 degrees. It was shielded by sandbags at its original location and did not move until after the blast wave had passed. The cable was covered with sand in the vicinity of ground zero. A hard-wire timing signal was used to activate a control circuit at H−5 minutes. This circuit started the crater survey cable winch at H+5 minutes. A recorder located at the cable winch, 137 degrees and 600 feet from ground zero, was used to record the radiation intensities encountered by the probe.

2.4.4 Alpha Survey. The concrete slabs were placed around ground zero prior to the shot, in the pattern shown in Figure 2.1. A background survey was taken at the time the slabs were placed. At approximately H+30 minutes, two project personnel with PAC-3G gas-flow proportional alpha counters drove to the nearest concrete slab, debarked, and took readings at three points on the surface of the slab. They then proceeded toward ground zero and repeated the above procedure at each survey point. The same readings were taken again on D+1 and D+2.

Before the shot, three low-volume air samplers were placed 300 feet from ground zero on azimuths of 150, 270, and 324 degrees. Two additional samplers were placed at 600 feet on azimuths of 304 and 330 degrees. The samplers were activated by a signal at H−1 second. At H+1 hour the filter papers from these samplers were recovered. They were then counted by a modified General Electric scintillation counter and a Tracerlab 100 scaler.

2.4.5 Fallout Collection. Four open-close collectors were placed 600 feet from ground zero on azimuths of 150, 165, 300, and 330 degrees. An additional collector was placed at 300 feet, 270 degrees. The fallout collectors were activated by a signal at H−1 second.

At H+15 minutes, two project personnel departed Site Elmer by helicopter to Station 1610 at the north end of Site Yvonne and from there by jeep to the fallout collectors 600 feet from ground zero on the 300-degree and 330-degree azimuths. Upon arrival at the fallout collectors, they measured the radiation intensity at 3 feet above the ground. They then removed the fallout samples, returned to the helicopter, flew to the south side of Site Yvonne, and transferred the samples to a waiting helicopter that returned the samples to the laboratory on Site Elmer. There the fallout samples were transferred to beakers, weighed, and the radiation intensity determined. Then part of each sample was transferred to a petri dish, stabilized with a mixture of silicone and toluene, and used for decay measurements. The remaining samples were transferred to polyethylene bottles. To preserve the particles for later study, the bottles were filled with nitrogen, sealed with wax, packed into a lead-lined box, and transported by courier to the Chemical Warfare Laboratories (CWL) for analysis. The detailed procedures for the radiochemical and radiophysical analysis are described in Appendix B.

Fifty-seven open-type collectors (buckets) were placed in a polar-coordinate grid system at 15-degree intervals starting approximately 200 feet and extending to 600 feet from ground zero. Six additional buckets were placed on Project 34.8 barges, one on each of the small barges and two on the large barge. One of the small barges was 2,100 feet and the other three were 7,600 feet from ground zero. The large barge was 3,600 feet from ground zero. The locations of the buckets are shown in Table A.1. The collectors were covered with lids before the shot. At H−3 hours, the lids were removed and the inside of the buckets wiped with clean rags. At H+6 hours

the buckets were covered and the lids taped on securely. The sealed buckets were returned to the laboratory at Site Elmer. There they were uncovered and monitored in a fixed geometry, with the ionization chamber 2 feet from the top of the buckets. The fallout was then removed and the total weight and total activity determined. A few representative samples were used for determination of the gross gamma decay of the fallout.

No fallout samples were obtained from Shot Quince.

2.4.6 Weight and Activity of Fallout. The three gross-fallout samples which had the greatest activity (K-3, L-4, and N-2, Table A.6) were placed under a nitrogen atmosphere and transported to the CWL. There the samples were transferred to petri dishes, surveyed with a Technical Associates, Juno 3, alpha, beta, gamma survey meter, dried for 1 hour at 110 C, and weighed. A portion of each gross sample was examined with a Bausch and Lomb stereoscopic microscope for the presence of calcium oxide spheres. If calcium oxide was not present, a major part of each sample was subdivided into nine size-fractions by sifting for 30 seconds through 148-, 177-, 210-, 250-, 297-, 350-, 420-, and 840-micron U. S. standard sieves. Approximately 75 percent of each sieved fraction was dissolved as described in Appendix B for radiochemical analyses; the remaining portions were utilized in particle and gamma spectrometric studies.

2.4.7 Radiochemistry. In addition to the aforementioned dissolved size-fractionated samples, portions of the total samples were prepared for radiochemical analyses. Aliquots of the size-fractionated and total samples were analyzed for Mo^{99}, Ce^{144}, Ba^{140}, and Sr^{89}.

2.4.8 Examination of Individual Particles. Seven equal-weight samples of particles from the 420-to-840-micron size fraction from Station N-2 were weighed to ±0.05 mg. These samples were examined with a Bausch and Lomb stereoscopic microscope and their gross beta activity determined with a Sugarman-Los Alamos window flow counter RCL Mark 12 Model 11A. Samples were treated first with water and then with 6N HNO_3 to determine the fraction of the activity which could be leached out. The detailed procedures used for leaching and microscopic examination are given in Appendix C.

2.4.9 Gamma Spectrometry. Gamma spectra were taken of the three gross samples at H+51 hours, H+92 hours, and D+6 days to determine the dose-rate contributions from induced activities in the fallout. The samples were sealed in 5-ml beakers with rubber hydrochloride (pliofilm) and scotch tape, and placed on the center of a 3-by-3-inch NaI(T1) scintillation crystal joined to a 3-inch Dumont photomultiplier 6363 by ophthalmological jelly. The crystal and photomultiplier tube were canned as a unit in 5-mil aluminum that was coated on the inside with alpha alumina for maximum reflection. The scintillations produced in the crystal by the gamma rays were seen by the photomultiplier tube and the resulting pulses transmitted to an Atomic Instrument Company 520, 20-channel differential pulse-height analyzer equipped with a Model 312, super stable high-voltage supply operated at 840 volts.

The gamma spectrum for each sample was corrected for crystal efficiency by taking the number of counts per second in each channel and dividing that number by the efficiency of the NaI(T1) crystal (Reference 17) for the gamma energy corresponding to that channel. This normalized the original spectrum to 100-percent crystal efficiency. All the normalized counts per second for each channel were then added giving the total number of events occurring in the crystal over all energies. The same procedure was applied to a standard Na^{24} spectrum, and this spectrum was superimposed on the spectrum of the sample. The sum of the events occurring in the crystal resulting from Na^{24} was then divided by the sum of the events resulting from the original sample. This gave the percent contribution of Na^{24} to the total gamma activity of the original sample. The method is estimated to be accurate within ±40 percent.

Chapter 3
RESULTS and DISCUSSION

3.1 SHOT QUINCE

Shot Quince was intended to be a test of a surface burst of a fractional-kiloton device. However, no nuclear explosion occurred; the resulting contamination consisted entirely of alpha particles. Nevertheless, a helicopter-to-ground aerial survey was made and two open-close collector cones were recovered. No gamma radiation was found in either case.

3.1.1 Alpha Survey. Surface alpha monitoring was conducted throughout the area on D and D+1 day. Figure 3.1 is a plot of the results obtained in micrograms per square meter. The markings coral, plywood, etc. indicate the nature of the surfaces on which the readings were taken. The instrument readings are listed in Table A.2. These readings were taken in counts per minute, corrected for the probe area, and multiplied by the appropriate shielding factors to compensate for the roughness of the surface monitored. The shielding factors for concrete pads and wood are based upon results obtained by Program 74 of Project 57, Operation Plumbbob. The other shielding factors were chosen arbitrarily in comparison with the above values. The factors used were 2.1 for concrete pads, 1.5 for smooth concrete, 1.75 for wood, and 4.0 for coral rock and sandbags. To convert the instrument readings into micrograms per square meter, they were divided by a factor of 420. This factor was obtained as follows: There are 1.38×10^5 (dis/min)/μg of plutonium; the sensitive area of the probe was 61 cm^2; there are 1×10^4 cm^2 in 1 m^2; therefore, for 2-pi geometry, 1 μg of plutonium per m^2 is equal to:

$$\frac{1.38 \times 10^5 \text{ (dis/min)}/\mu g \times 61 \text{ cm}^2}{2 \times 1 \times 10^4 \text{ cm}^2/\text{m}^2} = 420 \frac{\text{dis/min}}{\mu g/\text{m}^2}$$

A contaminated area was located in the downwind direction. No alpha activity found in the downwind area was in excess of 3,500 $\mu g/m^2$, which is the latest recommended tolerance level (Reference 18). Some of the measurements in this area gave alpha-contamination levels in excess of 1,000 $\mu g/m^2$, which is the level above which decontamination is recommended (Reference 18).

The alpha contamination was very spotty. Pieces of plutonium caused some hot spots in the downwind area. Movement and redistribution of the activity is obvious from a comparison of the D and D+1 day readings.

3.1.2 Air Sampling. Air samples collected during the time interval from H hour to H+1 hour and from H+1 to H+19 hours are recorded in Table 3.1. Plutonium concentrations were determined by counting the samples in a scintillation counter 2 days after collection, thus permitting all collected, naturally occurring alpha emitters such as radon and thoron to decay. The J-3 air sampler at 300 feet downwind was the only one that showed a reading above 100 (dis/min)/m^3 which is the continuous occupancy level for 1 month during an emergency (Reference 19). The H hour to H+1 hour samples of the F-2 air sampler at 300 feet and 150 degrees, and the Z-1 air sampler at 300 feet and 324 degrees were above the maximum permissible air concentration for plutonium in the bone of 1.3 (dis/min)/m^3 for continuous lifetime occupancy established by the International Commission on Radiation Protection. The high concentration of plutonium collected by the J-3 sampler from H+1 to H+19 hours may have been caused by the movement of

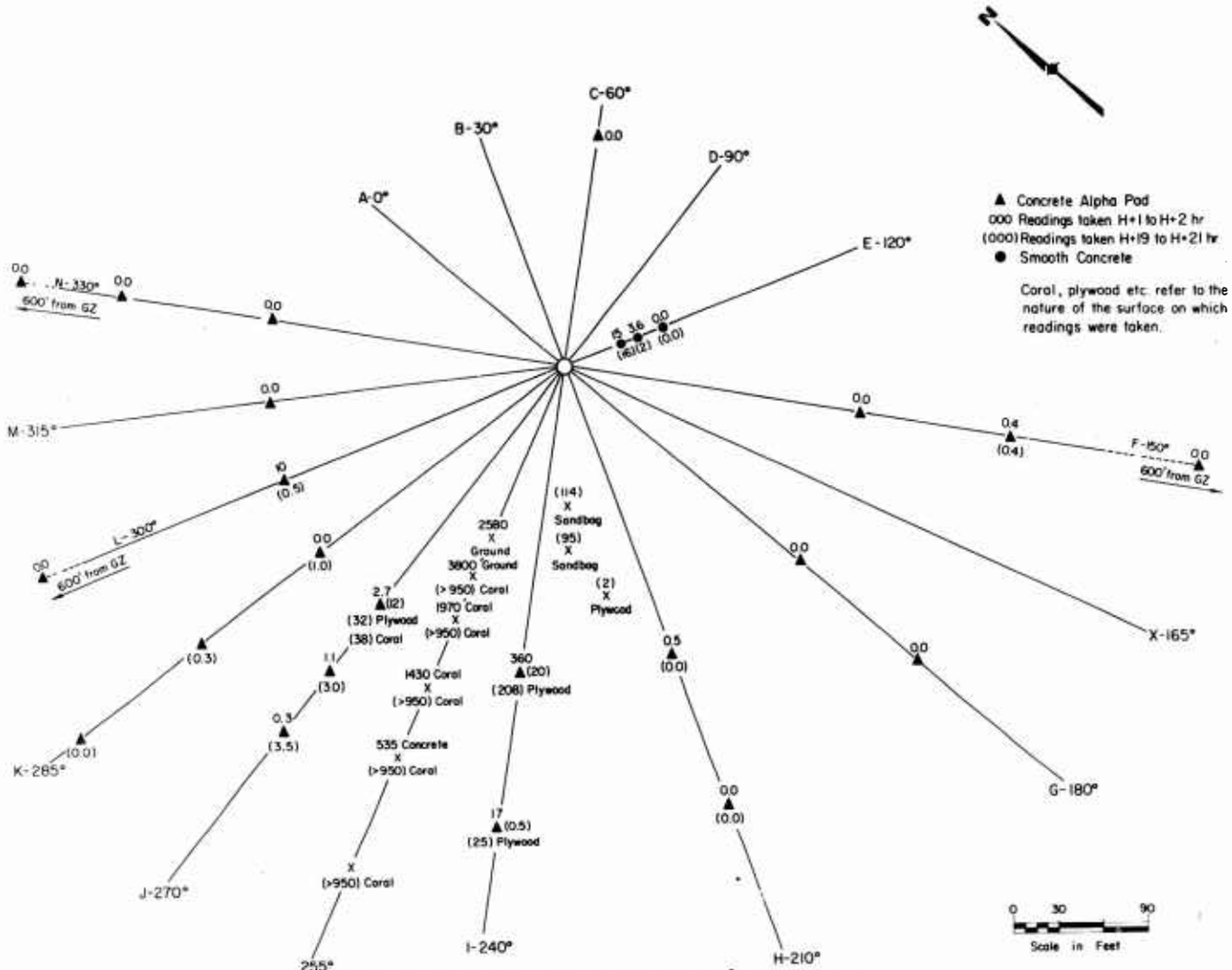


Figure 3.1 Alpha survey readings in $\mu g/m^2$, Shot Quince.

the contamination from the ground-zero area downwind. Even this alpha concentration in the air was less than 2 percent of the emergency exposure of 50,000 (dis/min)/m^3 for 1 hour (Reference 19). A sample calculation for determining the alpha air concentration is shown in Appendix A.

3.2 SHOT FIG

This project participated successfully during Shot Fig and obtained useful data. All equipment operated successfully, with the exception of one open-close fallout collector and the crater-survey instrument. Of the 57 open-type collectors, 47 were recovered. The remaining ten were blown away or damaged beyond possibility of recovery by the blast.

TABLE 3.1 SUMMARY OF ALPHA CONCENTRATION IN THE AIR, SHOT QUINCE

Station	Azimuth From Ground Zero	Distance From Ground Zero	Start Of Sampling	Duration Of Sampling	Volume of Air Sampled	Alpha Concentration
	deg	ft	hr	min	m^3	(dis/min)/m^3
F-2	150	300	0	43	5.6	20.2
J-3	270	300	0	50	9.5	265
L-4	305	600	0	58	12.0	0.4
N-4	330	600	0		Failed to operate	
Z-1	324	300	0	63	11.1	5.76
F-2	150	300	1	1,080	139	0.74
J-3	270	300	1	1,100	209	966
L-4	305	600	1	1,080	139	0.2
N-4	330	600	1		Failed to operate	
Z-1	324	300	1	1,110	196	0.1

3.2.1 Gamma Ground Survey. The gamma ground survey was performed by the recovery parties. The data together with H+1 hour values are presented in Table A.7. In order to correct the gamma dose-rate survey readings to H+1 hour, laboratory gamma dose-rate decay measurements were made of fallout samples L-4, N-2, and K-3. The decay curves for these samples normalized to H+1.98 hour are shown in Figure 3.2. The original readings together with the values used for plotting are listed in Tables A.3, A.4, and A.5. A composite decay curve of these samples, Figure 3.3 was used to correct the gamma dose-rate survey readings to H+1 hour. The average H+1 hour values so obtained and the H+1 hour isodose lines are plotted in Figure 3.4. It can be seen that the hot line of the fallout pattern falls close to 270 degrees. This figure also shows that the 200 r/hr isodose line extended 150 feet crosswind. Although no data is available to close the 200 r/hr downwind contour it is estimated that it might close around 325 feet. The 100 r/hr dose-rate contour extended 200 feet crosswind. The downwind length cannot be determined, because it extends into the lagoon. The predicted dose-rates for a 0.025-kt surface burst from Reference 20 are shown in Table 3.2.

3.2.2 Aerial Survey. It is of interest to note that several readings taken at H+26 minutes by means of the helicopter-to-ground survey system in the vicinity of the crater were off-scale on the Kr/hr scale, i.e., greater than 10,000 r/hr. On the next sweep over the island, the probe was accidently dipped in the lagoon because of poor visibility. The instrument became inoperable and was returned to Site Elmer for drying and checking. At H+17 hours and H+21 hours, additional surveys were made. A calibration curve was obtained during the interval between these two surveys. The calibration curve is shown in Figure A.1, and the aerial survey readings together with the corrected H+1 hour values are shown in Table A.8. These values are low by a factor of five compared to the ground survey readings in Table A.7. The reason for this discrepancy is unknown.

3.2.3 Crater Survey. The crater-survey instrument received the signal at H−5 minutes, starting the timer and the chart-drive motor on the Brown recorder. At zero time, the recorder registered an initial gamma pulse off-scale, greater than 10,000 r/hr, for approximately 7 seconds. The radiation level then decreased to less than 10 r/hr by H+6 minutes. These readings

were apparently caused by the passage of the cloud. The probe during this time was located at its original position, 375 feet from ground zero on an azimuth of 317 degrees. The probe apparently moved no farther than 50 feet toward ground zero. When the instrument was recovered, the cable was found to have been tangled and broken by Sandia Corporation's sled cable. Also the glass front on the Brown recorder had been shattered, probably by the blast.

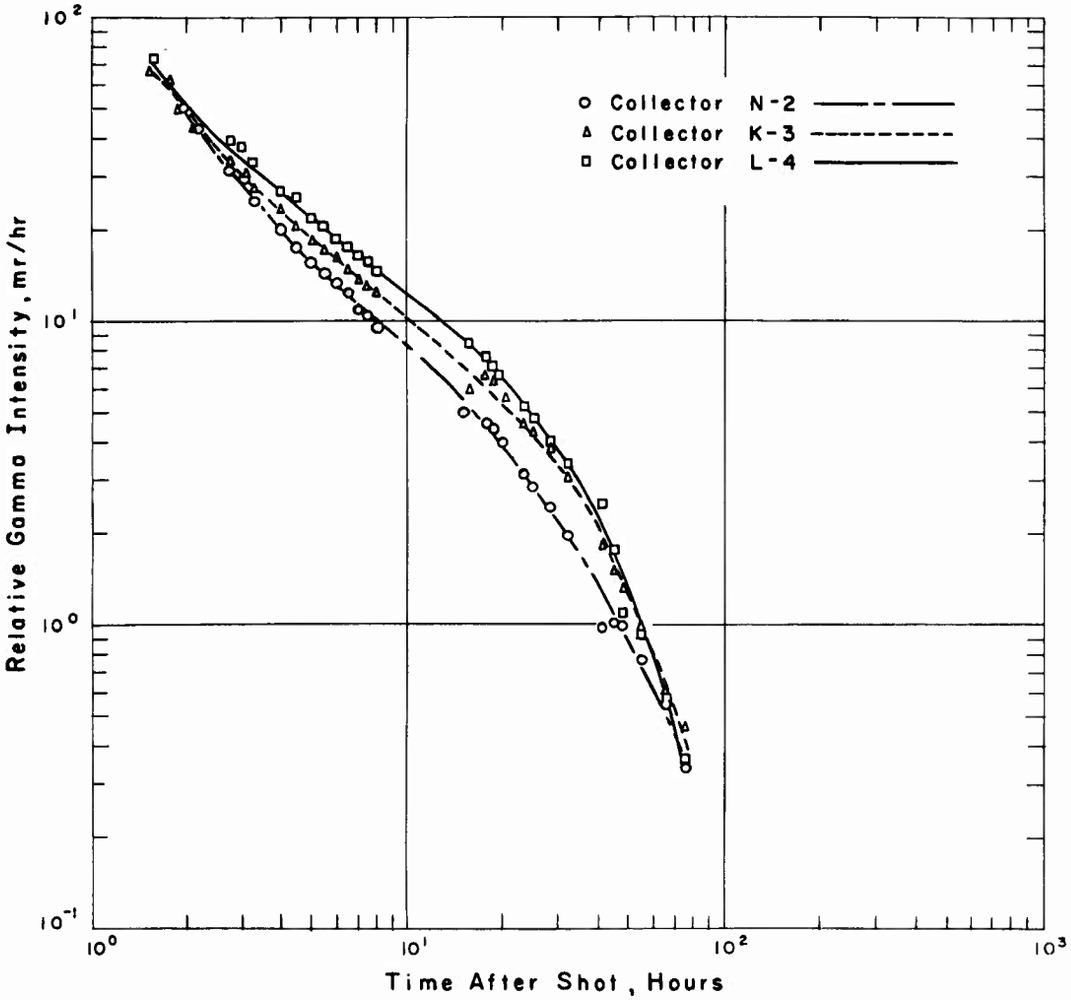


Figure 3.2 Decay curves for fallout samples, K-3, L-4, and N-2 normalized to H+1.98 hour, Shot Fig.

3.2.4 Alpha Survey. No detailed alpha survey was made. A rough survey indicated no increase of the alpha contamination due to Shot Fig, only redistribution. The results of the air samples are presented in Table 3.3. These readings do not represent the alpha concentration from the Fig device, because the area was already contaminated with alpha emitters from Shot Quince.

3.2.5 Weight and Activity of Fallout. The amount of fallout collected in grams per square centimeter and its relative radiation intensities are given in Figure 3.5. It can be seen that the weight collected decreased with distance. The greatest amount of fallout was collected on the

240-degree azimuth at 200 feet from ground zero. However, indications are that the collector on the 270-degree azimuth, at the same distance, would have collected more, if it had not been destroyed. The collectors at 270 degrees had the greatest amount of fallout for the stations 300 feet from ground zero. At the stations where fallout was heavy, the four collectors collected approximately the same amount of material; however, the activity varied among collectors.

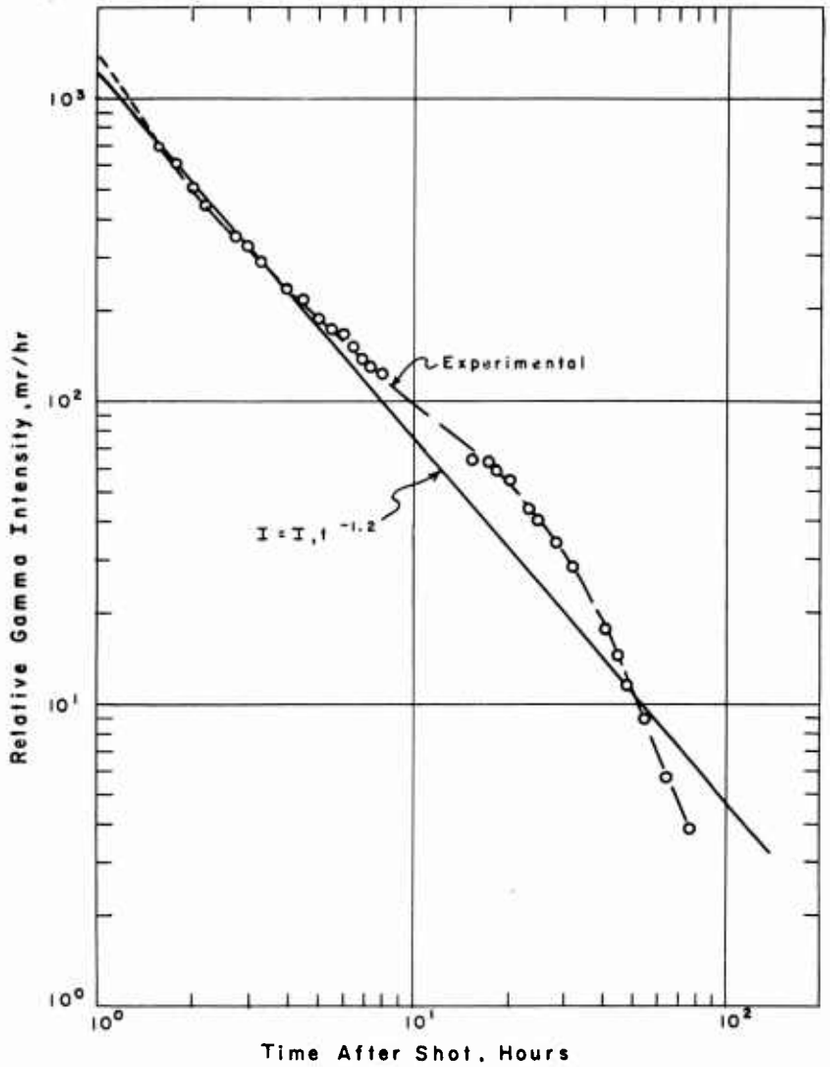


Figure 3.3 Composite decay curve of fallout samples, Shot Fig.

The weights and activities of the three gross-fallout samples returned to the CWL are shown in Table 3.4. These samples came from Stations K-3, 400 feet downwind from ground zero close to the hot line; Station N-2, 300 feet from ground zero in the crosswind direction; and Station L-4, 600 feet from ground zero. The fallout material from these collectors consisted entirely of solid fallout; no liquid fallout was found in these samples. No rain fell between shot time and recovery time.

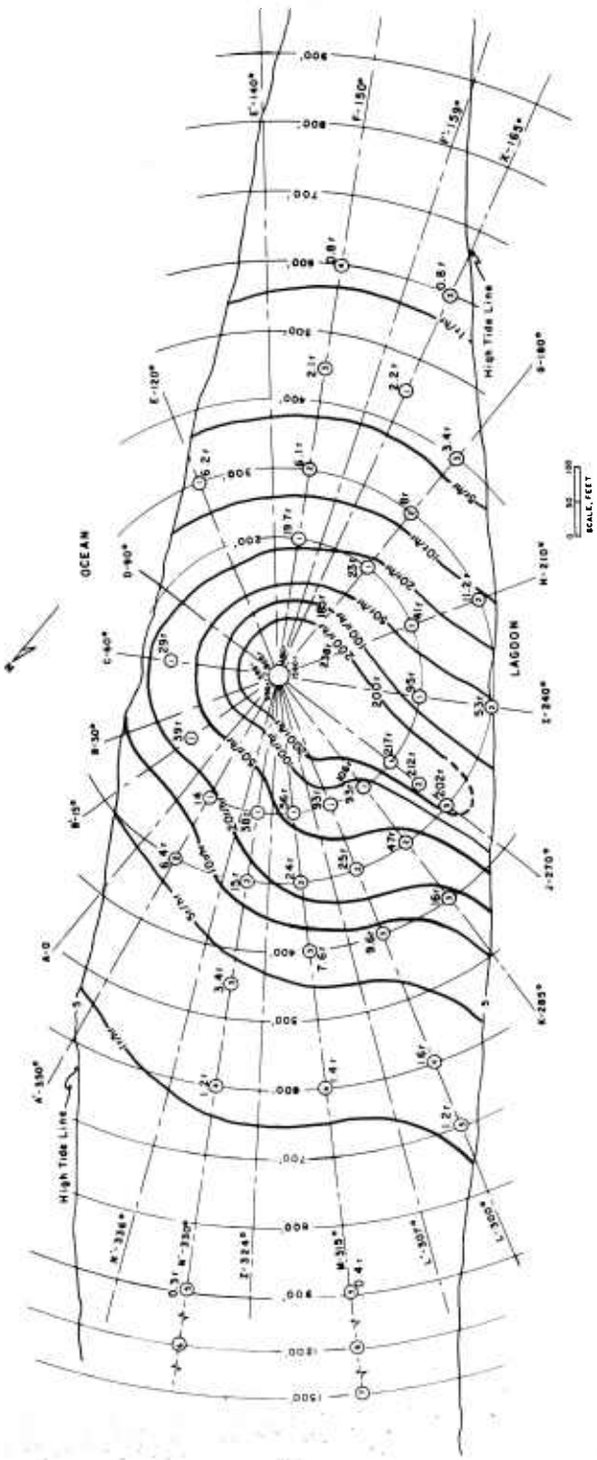


Figure 3.4 Dose rate in r/hr at H+1 hour, Shot Fig.

TABLE 3.2 ESTIMATED RESIDUAL RADIATION FOR A 0.025-KT SURFACE BURST AT H + 1 HOUR*

Intensity	Distance Downwind From Ground Zero	Distance Crosswind From Ground Zero
r/hr	ft	ft
1,000	135	75
300	480	150
100	1,155	285
30	3,270	465

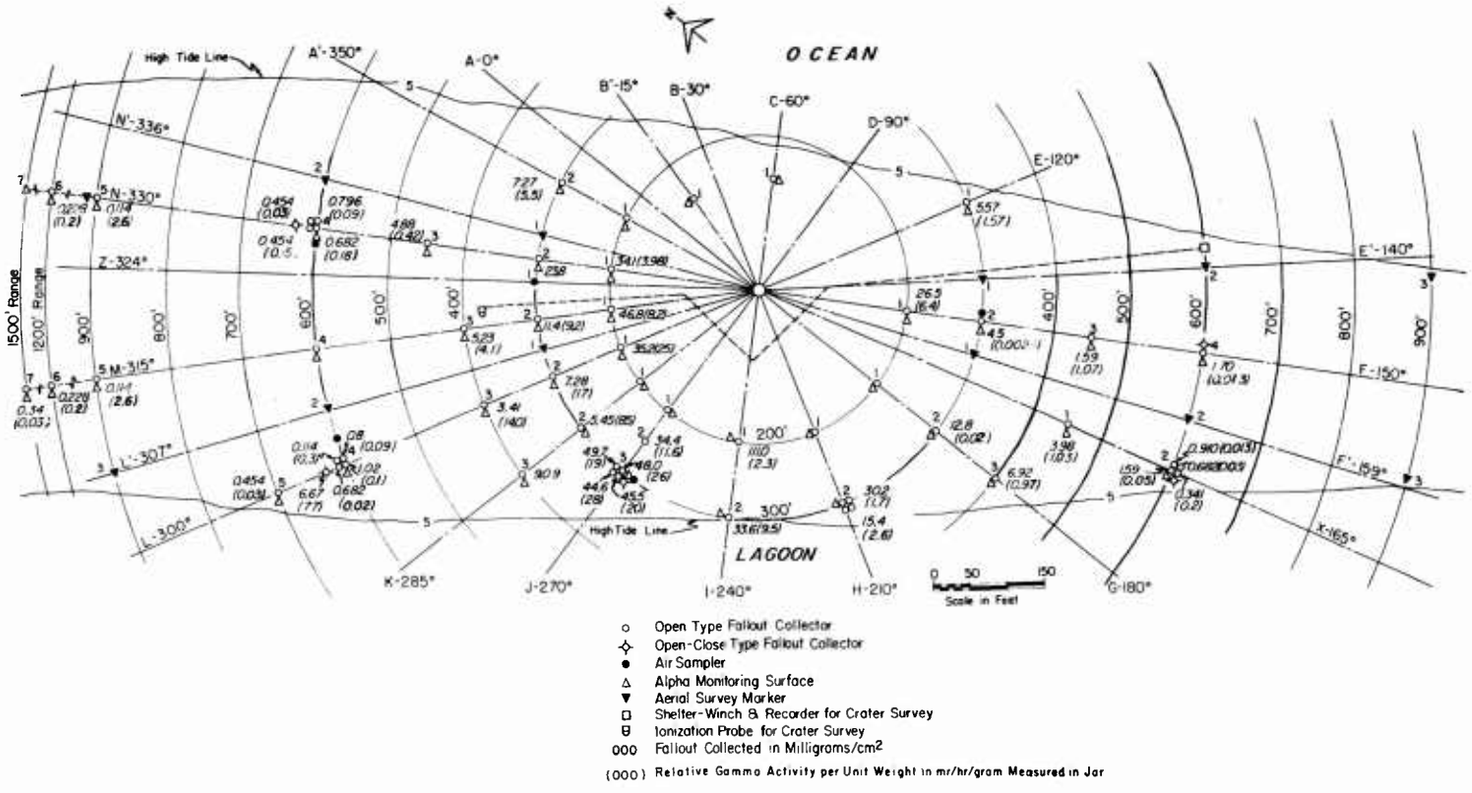
* Values taken from Reference 20.

TABLE 3.3 ALPHA AIR CONCENTRATION, SHOT FIG

Station	Azimuth From Ground Zero	Distance From Ground Zero	Duration of Sampling	Volume Of Air Sampled	Alpha Concentration
	deg	ft	min	m^3	$(dis/min)/m^3$
F-2	150	300	210	27.1	0.34
J-3	270	300	1,020	194	570
L-4	305	600	210	44	3.46
Z-1	324	300	210	37	12

TABLE 3.4 WEIGHT AND ACTIVITY OF FALLOUT SAMPLES UPON ARRIVAL AT CWL

Sample	Weight	Time After Shot	Distance Above Sample	Gamma Dose Rate	Gamma Activity	Beta Plus Gamma Activity	Beta Plus Gamma Activity
	grams	hr	in	mr/hr	(mr/hr)/gm	mr/hr	(mr/hr)/gm
K-3	7.063	47.0	0.5	140	20	>5,000	—
			6	22	3.1	800	110
L-4	17.978	47.0	0.5	80	4.5	1,400	78
			6	13	0.72	240	13
N-2	19.949	47.0	0.5	320	16	>5,000	—
			6	45	2.3	1,600	80



- Open Type Fallout Collector
- Open-Close Type Fallout Collector
- Air Sampler
- Alpha Monitoring Surface
- Aerial Survey Marker
- Shelter-Winch & Recorder for Crater Survey
- Ionization Probe for Crater Survey
- 000 Fallout Collected in Milligrams/cm²
- (000) Relative Gamma Activity per Unit Weight in mr/hr/gram Measured in Jar

Figure 3.5 Weight of fallout and relative gamma activity, Shot Fig.

These samples were separated into different groups by size, and the weight and beta activity of each sieved fraction determined. The results are shown in Table 3.5. The particle-size groups are a rough approximation. Experience has shown that the average size usually corresponds to the upper limit of the sieve range. The relative weight distributions in the size-grouped-fallout samples are roughly similar at all three stations. Thirteen to seventeen percent by weight of the fallout was in the group under 149 microns, while 51 to 61 percent was in the larger-than-420-micron fraction.

TABLE 3.5 RELATIVE WEIGHTS AND ACTIVITIES IN SIEVED FRACTIONS OF FALLOUT SAMPLES, SHOT FIG

Station, Distance, And Azimuth From Ground Zero	Size Fraction	Weight Of Fraction	Total Weight Of Sieved Fractions	Beta Activity In Fraction At H+240 Hours
	microns	grams	pct	pct
K-3, 400 ft, 285 deg	<148	0.4465	15.1	33.9
	148 to 177	0.0830	2.81	0.46
	177 to 210	0.1956	6.62	0.81
	210 to 250	0.1641	5.56	0.26
	250 to 297	0.2106	7.13	0.98
	297 to 350	0.2044	6.92	0.96
	350 to 420	0.1310	4.44	0.54
	420 to 840	0.4420	15.0	6.78
	>840	1.0755	36.4	55.3
L-4, 600 ft, 300 deg	<148	1.0955	17.0	22.9
	148 to 177	0.1752	2.72	2.98
	177 to 210	0.3176	4.94	7.40
	210 to 250	0.2428	3.78	6.18
	250 to 297	0.3402	5.29	4.71
	297 to 350	0.3214	5.00	5.12
	350 to 420	0.2382	3.70	6.32
	420 to 840	1.5491	24.1	23.1
	>840	2.1504	33.4	21.2
N-2, 300 ft, 330 deg	<148	1.0916	13.1	9.87
	148 to 177	0.2399	2.87	2.07
	177 to 210	0.4214	5.04	4.04
	210 to 250	0.3310	3.96	2.47
	250 to 297	0.4345	5.20	5.17
	297 to 350	0.4085	4.89	6.39
	350 to 420	0.3119	3.73	5.88
	420 to 840	1.3698	16.4	30.3
	>840	3.7514	44.9	33.8

3.2.6 Radiochemistry. Portions of the same three samples (K-3, L-4, and N-2) which were returned to the CWL were used for analyses of selected fission products. The results of these analyses are summarized in Tables 3.6 through 3.8 and are discussed in Sections 3.2.7 through 3.2.9. The tables show the activity concentrations of each nuclide at zero time, the relative beta-activity concentration at H+240 hours after the shot, the relative contribution of the nuclides analyzed to total beta activity at H+240 hours, and the R values of the nuclides analyzed. R-value is defined as $(A_a/B_a)/(A_{th}/B_{th})$ where the subscript a refers to any nuclear event and the subscript th refers to thermal neutron fission of uranium. B is usually Mo^{99} but can be any other nuclei. It is believed that the data on the Mo^{99} and Ba^{140} are generally accurate to ±15 percent. The Sr^{90} and Ce^{144} counting activities were quite low, causing poor counting statistics; these data are believed to be accurate to ±30 percent. The precision for each analysis is indicated as percent standard deviation.

3.2.7 Beta-Activity Concentration. The beta-activity concentrations at the three stations are shown in Table 3.6. At K-3, the close downwind station, the Mo^{99}, Ba^{140}, Ce^{144} results decrease with increasing particle size up to 250 microns and then increase. For the larger-than-840-micron fraction, the values are higher by a factor of 50 than those for the other groups. At L-4, the more distant station, the Mo^{99}, Ba^{140}, Ce^{144} values were generally lower than at K-3. This tendency was especially pronounced in the larger-than-840-micron fraction. The values at N-2, the close crosswind station, are higher than the corresponding values for similar particle-size groups at K-3 except for the larger-than-840-micron group that showed values 7 to 10 times smaller than the results at K-3. The maximum activity concentrations at K-3 and N-2 are always in either the 420-to-840-micron group or the larger-than-840-micron group.

TABLE 3.6 BETA-ACTIVITY CONCENTRATIONS IN FALLOUT SAMPLES, SHOT FIG

Station	Size Fraction	Microcuries/Milligram At Zero Time				Total Beta Activity At H + 240 Hours
		Mo^{99}	Ba^{140}	Ce^{144}	Sr^{89}	
	microns	10^{-4} μc/mg ± pct σ	10^{-5} μc/mg ± pct σ	10^{-4} μc/mg ± pct σ	10^{-6} μc/mg ± pct σ	(counts/min)/mg
K-3	<148	61.2 ± 2.9	42.3 ± 2.2	22.5 ± 29	10.7 ± 2.9	728
	148 to 177	59.2 ± 3.1	29.3 ± 1.8	17.3 ± 13	— —	527
	177 to 210	40.1 ± 3.5	20.8 ± 3.7	11.8 ± 3.1	— —	396
	210 to 250	17.1 ± 0.6	8.6 —	— —	— —	149
	250 to 297	49.1 ± 4.0	25.1 ± 7.2	17.0 ± 15	6.53 ± 4.7	446
	297 to 350	38.6 ± 2.0	20.0 ± 5.6	— —	6.58 ± 12	448
	350 to 420	48.1 ± 1.2	23.2 ± 0.1	— —	5.95 ± —	399
	420 to 840	225 ± 3.1	92.2 ± 0.1	47.3 ± 8.7	19.2 ± 4.1	1,469
	>840	996 ± 9.6	492 ± 3.9	279 ± 5.1	82.9 ± 3.6	1,209
Unsieved sample		25.7 ± 3.1	12.7 ± 1.8	11.8 ± 41	2.48 ± 6.4	250
L-4	<148	22.0 ± 2.2	16.0 ± 5.0	6.17 ± 10	5.00 ± 16	218
	148 to 177	13.2 ± 0.1	9.10 ± 5.0	4.86 ± 9.2	— —	177
	177 to 210	19.4 ± 2.6	12.0 ± 4.8	6.13 ± 10	— —	242
	210 to 250	14.7 ± 5.7	11.7 ± 4.9	3.82 ± 19	4.50 ± 0.3	265
	250 to 297	9.62 ± 20	8.20 ± 4.5	3.86 ± 33	9.05 ± 17	144
	297 to 350	14.1 ± 8.7	10.2 ± 9.7	4.14 ± 6.0	4.55 ± 18	166
	350 to 420	14.2 ± 6.3	12.2 ± 12	6.31 ± 12	3.74 ± 19	276
	420 to 840	14.5 ± 2.3	8.47 ± 0.2	4.16 ± 5.5	3.78 ± 39	155
	>840	8.23 ± 5.2	7.30 ± 25	2.80 ± 24	5.81 ± 23	103
Unsieved sample		25.3 ± 3.1	11.4 ± 2.6	6.22 ± 25	3.78 ± 2.0	206
N-2	<148	119 ± 2.5	51.8 ± 1.6	24.9 ± 24	9.95 ± 2.2	961
	148 to 177	113 ± 1.1	51.4 ± 5.8	26.2 ± 6.6	12.9 ± 35	915
	177 to 210	85.7 ± 5.3	53.3 ± 4.1	29.5 ± 3.8	11.5 ± 2.8	1,023
	210 to 250	125 ± 1.0	60.6 ± 0.2	33.4 ± 7.5	19.5 ± 2.6	793
	250 to 297	157 ± 5.3	59.3 ± 11	59.9 ± 4.3	11.9 ± 6.7	1,265
	297 to 350	186 ± 2.5	86.7 ± 2.9	— —	6.08 ± 1.0	1,659
	350 to 420	236 ± 2.4	123 ± 22	— —	20.7 ± 12	2,005
	420 to 840	439 ± 5.8	147 ± 8.3	105 ± 5.9	29.8 ± 5.0	2,350
	>840	130 ± 3.3	70.2 ± 4.8	26.7 ± 4.7	13.7 ± 1.5	961
Unsieved sample		273 ± 0.6	144 ± 8.2	104 ± 4.1	4.50 ± 6.4	3,182

3.2.8 Relative Contribution of Nuclides to Total Beta Activity. The relative contribution of nuclides to total beta activity at H+240 hours is shown in Table 3.7. At that time, the percentage of total activity contributed by the nuclides analyzed amounted to 28 to 69 percent of the beta activity present. It is possible that the iodine and ruthenium fission products were driven off by the procedure used to dissolve the sample; therefore, the percentages indicated may be high.

There appeared to be no well-defined trends of the percent contribution of individual nuclides to beta activity with particle size. However, it appears that the ratio of Mo^{99} to total beta activity is generally greater at the closer stations, K-3 and N-2, than at L-4.

3.2.9 R-Values. The R-values are shown in Table 3.8. The R-values, in general, showed no well-defined trend with particle size or location. The R-values for cerium/molybdenum were more constant at all stations than the R-values of other nuclides.

3.2.10 Gamma Spectrum. At H+51 hours, the gamma-ray spectrum of aliquots of fallout samples from Stations K-3, L-4, and N-2, showed a very prominent Na^{24} spectrum. These spectra were still identifiable at H+92 hours but not at D+6 days.

Because the spectrometer was not calibrated for quantitative determinations of the various nuclides in the spectra, the percentage contribution of Na^{24} to the total gamma activity was estimated by the method described in Section 2.4.9. By this method of normalization, the estimated contribution of Na^{24} to the total gamma activity at K-3, L-4, and N-2, was 76, 66, and 40 percent respectively, at H+51 hours. At the same time, the extrapolated beta activity of the fission products analyzed contributed about 10 percent of the total beta activity. Figure 3.6 shows the original spectra of an aliquot of sample L-4 with the Na^{24} spectrum fitted to it. Figure 3.7 shows the normalized spectra of the aliquot and the Na^{24} spectrum also fitted to it. The energy peaks of probable nuclides contributing to the gamma spectrum are indicated in Figures 3.6 and 3.7.

TABLE 3.7 RELATIVE CONTRIBUTION OF NUCLIDES TO TOTAL BETA ACTIVITY AT H + 240 HOURS, SHOT FIG

Station	Size Fraction	Sr^{89} / Total Beta	Mo^{99} / Total Beta	Ba^{140} / Total Beta	Pr^{144} / Total Beta	Total Contribution Of These Nuclides To Total Beta Activity
	microns	pct	pct	pct	pct	pct
K-3	<148	0.36	20.2	10.8	1.05*	32.4
	148 to 177	—	26.9	10.3	1.12	38.3
	177 to 210	—	24.1	9.7	1.01	34.8
	210 to 250	—	27.4	10.7	—	38.1
	250 to 297	0.36	26.4	10.6	1.31†	38.7
	297 to 350	0.36	20.6	8.2	—	29.2
	350 to 420	0.36	29.0	10.7	—	40.1
	420 to 840	0.32	36.7	11.6	1.09	49.7
	>840	0.41	48.4	18.5	1.97	69.3
Unsieved sample		0.24	24.6	9.4	1.59*	35.8
L-4	<148	0.56†	24.1	13.6	0.96	39.1
	148 to 177	—	18.0	9.4	0.92	28.3
	177 to 210	—	19.0	9.1	0.85	29.0
	210 to 250	0.14	13.4	8.2	0.49†	22.2
	250 to 297	1.5†	15.8†	10.5	0.90*	28.7
	297 to 350	0.67†	20.3	11.5	0.85	33.3
	350 to 420	0.0033†	12.2	8.2	0.78	21.2
	420 to 840	0.59*	22.4	10.1	0.91	34.0
	>840	1.4†	18.8	13.3†	0.93†	34.4
Unsieved sample		0.45	29.7	10.3	1.03†	41.5
N-2	<148	0.25	30.9	10.5	0.92†	42.6
	148 to 177	0.34*	29.7	10.4	0.97	41.4
	177 to 210	0.27	20.1	9.7	0.98	31.0
	210 to 250	0.60	26.4	9.9	1.00	37.9
	250 to 297	0.23	29.7	8.7	1.61	40.2
	297 to 350	0.094	27.6	9.8	—	37.5
	350 to 420	0.25	28.2†	11.4	—	39.8
	420 to 840	0.31	44.4	11.7	1.53	57.9
	>840	0.35	32.5	13.6	0.94	47.4
Unsieved sample		0.04	20.6	8.4	1.10	30.1

* Standard deviation of individual nuclide greater than 25 percent.

† Standard deviation of individual nuclide between 15 and 25 percent.

The gamma spectra of the fallout samples at H+51 hours showed that as much as 76 percent of the total activity at that time was due to Na^{24}; however, this would not be the case at H+1 hour. The extrapolation back to H+1 hour, using a decay factor of −1.2 for the fission products and a half-life of 15.0 hours for Na^{24}, indicates that at H+1 the induced activity from Na^{24} would contribute approximately 28 percent to the total gamma activity. This induced activity must have come from the NTS soil at ground zero.

The analysis of the NTS soil is given in Table 3.9. The amount of sodium reported in the analysis may be low. The soil sample was taken when the soil was placed in the crater; however, this was several weeks before Shot Fig. During the interval, more NaCl could have been introduced into the soil from the environment.

TABLE 3.8 R-VALUES FROM FALLOUT, SHOT FIG

R-value is defined as $(A_a/B_a)/(A_{th}/B_{th})$ where the subscript a refers to any nuclear event and the subscript th refers to thermal neutron fission of uranium. B is usually Mo^{99} but can be any other nuclei.

Station	Size Fraction	$\frac{Sr^{89}/Mo^{99}}{Sr^{89}_{th}/Mo^{99}_{th}}$ ± pct σ	$\frac{Ba^{140}/Mo^{99}}{Ba^{140}_{th}/Mo^{99}_{th}}$ ± pct σ	$\frac{Ce^{144}/Mo^{99}}{Ce^{144}_{th}/Mo^{99}_{th}}$ ± pct σ	$\frac{Sr^{89}/Ce^{144}}{Sr^{89}_{th}/Ce^{144}_{th}}$ ± pct σ	$\frac{Ba^{140}/Ce^{144}}{Ba^{140}_{th}/Ce^{144}_{th}}$ ± pct σ
	microns	pct	pct	pct	pct	pct
K-3	<148	0.045 ± 6.1	0.32 ± 5.8	0.89 ± 30	0.050 ± 29	0.36 ± 29
	148 to 177	— —	0.23 ± 5.7	0.70 ± 14	— —	0.32 ± 13
	177 to 210	— —	0.24 ± 6.8	0.71 ± 6.5	— —	0.34 ± 5.4
	210 to 250	— —	0.23 —	— —	— —	— —
	250 to 297	0.034 ± 7.7	0.24 ± 9.4	0.84 ± 16	0.041 ± 16	0.28 ± 17
	297 to 350	0.044 ± 12	0.24 ± 7.4	— —	— —	— —
	350 to 420	0.032 —	0.22 ± 7.8	— —	— —	— —
	420 to 840	0.22 ± 6.8	0.19 ± 5.4	0.50 ± 10	0.043 ± 10	0.37 ± 9.2
	>840	0.021 ± 11	0.23 ± 11	0.69 ± 12	0.031 ± 6.7	0.34 ± 6.8
	Weighted average	— —	0.24 —	— —	— —	— —
	Unsieved sample	0.025 ± 4.9	0.23 ± 5.7	1.1 ± 25	0.022 ± 41	0.20 ± 41
L-4	<148	0.058 ± 17	0.33 ± 7.0	0.68 ± 11	0.086 ± 19	0.49 ± 12
	148 to 177	— —	0.32 ± 6.7	0.89 ± 10	— —	0.36 ± 11
	177 to 210	— —	0.28 ± 7.0	0.76 ± 12	— —	0.37 ± 12
	210 to 250	0.078 ± 7.2	0.36 ± 8.7	0.62 ± 20	0.12 ± 19	0.58 ± 20
	250 to 297	0.24 —	0.41 ± 21	0.97 ± 39	0.25 —	0.40 ± 33
	297 to 350	0.082 ± 21	0.33 ± 14	0.71 ± 12	0.12 ± 20	0.47 ± 12
	350 to 420	0.067 ± 14	0.39 ± 14	1.1 ± 20	0.063 ± 22	0.37 ± 17
	420 to 840	0.067 ± 40	0.27 ± 4.9	0.69 ± 7.5	0.096 ± 40	0.39 ± 6.0
	>840	0.18 ± 24	0.41 ± 26	0.82 ± 25	0.22 ± 33	0.50 ± 34
	Weighted Average	— —	0.35 —	0.77 —	— —	0.45 —
	Unsieved sample	0.039 ± 4.9	0.21 ± 5.2	0.68 ± 25	0.065 ± 25	0.35 ± 25
N-2	<148	0.021 ± 5.6	0.20 ± 5.4	0.51 ± 24	0.042 ± 38	0.40 ± 24
	148 to 177	0.029 ± 35	0.21 ± 7.4	0.56 ± 8.1	0.052 ± 35	0.37 ± 9.1
	177 to 210	0.034 ± 7.5	0.29 ± 8.0	0.83 ± 8.0	0.042 ± 27	0.34 ± 6.0
	210 to 250	0.040 ± 8.8	0.22 ± 4.6	0.64 ± 5.2	0.062 ± 8.3	0.34 ± 7.9
	250 to 297	0.020 ± 9.6	0.17 ± 13	0.92 ± 8.2	0.021 ± 8.3	0.19 ± 12
	297 to 350	0.0085 —	0.21 ± 5.9	— —	— —	— —
	350 to 420	0.022 —	0.24 ± 22	— —	— —	— —
	420 to 840	0.018 ± 8.9	0.15 ± 11	0.58 ± 9.5	0.030 ± 8.1	0.27 ± 10
	>840	0.027 ± 5.7	0.25 ± 7.4	0.50 ± 7.3	0.054 ± 5.4	0.50 ± 7.1
	Weighted average	0.024 —	0.22 —	— —	— —	— —
	Unsieved sample	0.0042 ± 7.8	0.24 ± 9.4	0.91 ± 6.1	0.046 ± 7.9	0.26 ± 9.4

3.2.11 Examination of Particles. Detailed examination of the particles was limited to the 420-to-840-micron group from Station N-2. The samples were first washed with water to remove silt that obscured the individual particles. Some of the samples were subsequently washed with 6N nitric acid, along with samples of native NTS soil. The effects of these washings are shown in Table 3.10.

For the acid wash, the threefold-greater loss in weight of the fallout compared to that of the native NTS soil indicated that the detonation displaced coral as well as the implanted NTS soil. This inference is supported by the observation of fallout particles derived from coral and by calcium analysis which showed 7 percent in NTS soil and 21 percent in the fallout.

For the water wash, the 11-percent increase in measured activity suggests that the silt screened out low-energy beta particles.

On the basis of microscopic examination, the water-washed fallout particles were classified into four types: (1) fused, (2) white or yellow opaque, (3) tan opaque, and (4) miscellaneous. Types 3 and 4 were also observed in native NTS soil. The distribution of the particle types by weight and activity is shown in Table 3.11.

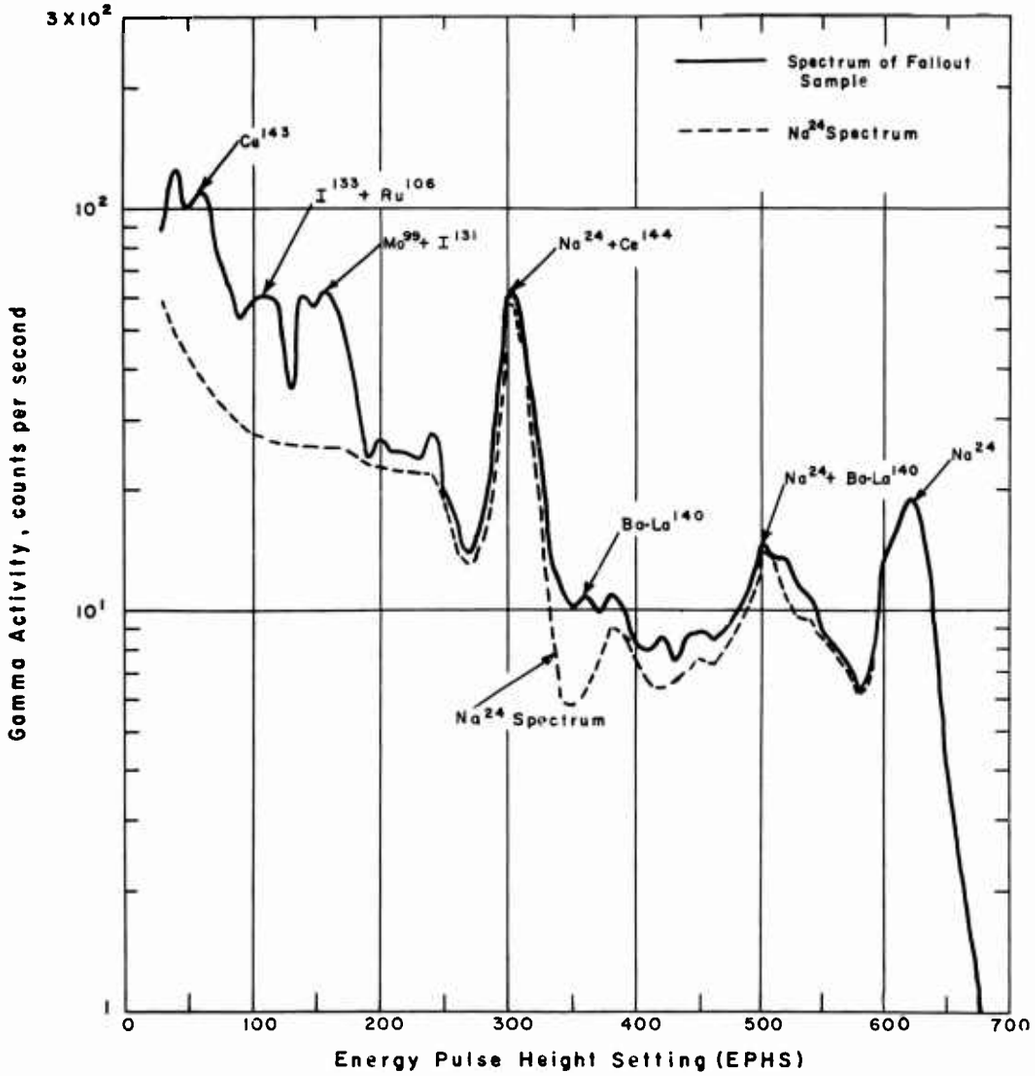


Figure 3.6 Gamma spectrum at H + 51 hours of fallout sample from Station L-4.

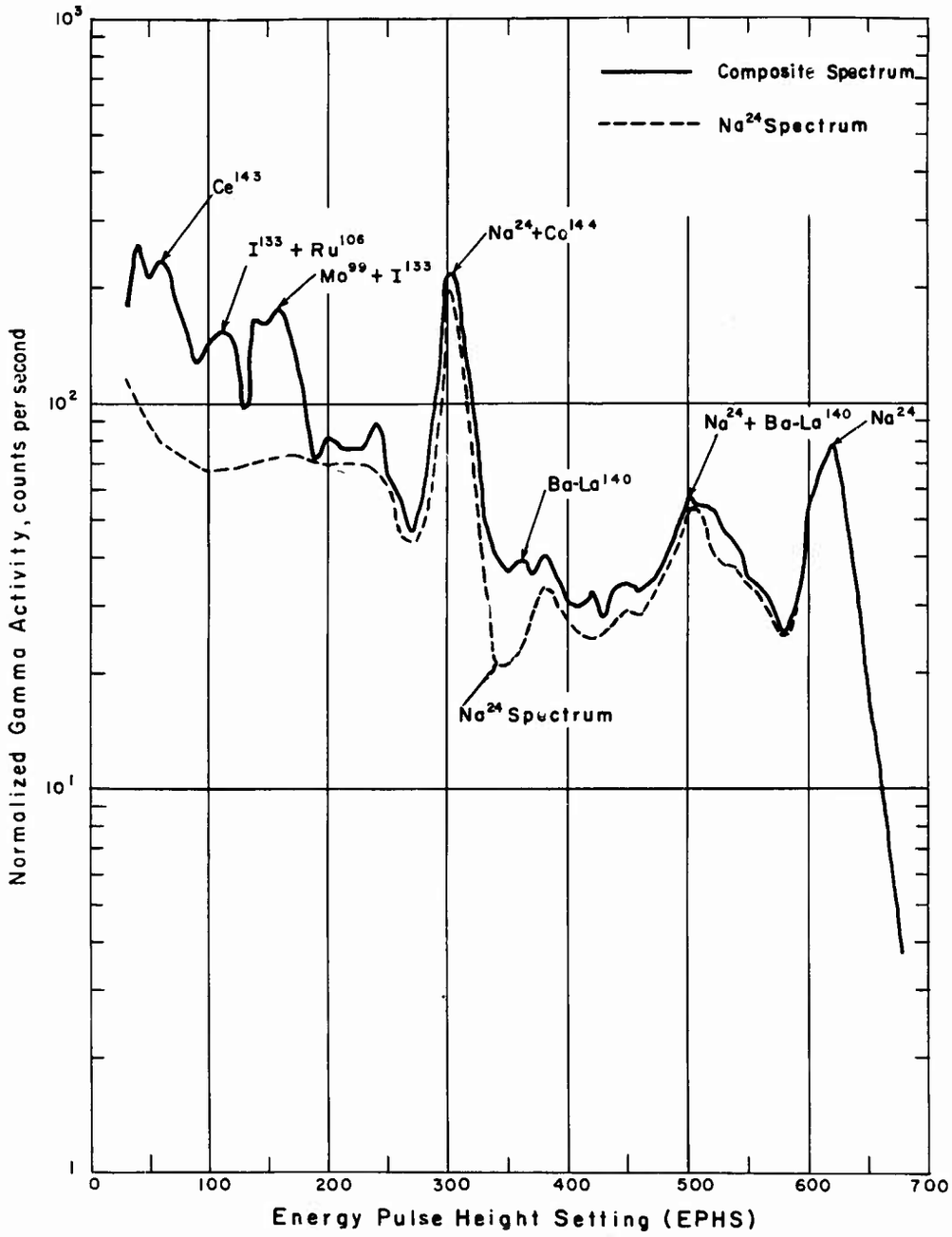


Figure 3.7 Normalized gamma spectrum at H+51 hours of fallout sample from Station L-4.

TABLE 3.9 ANALYSIS OF SOIL FROM AREA 10, NTS

Density of soil was about 1.67 g/cc

Element	Percent Of Total Weight*
Silicon	25.9
Calcium	7.1
Aluminum	3.0
Magnesium	2.5
Iron	1.2
Titanium	0.82
Sodium	0.14
Phosphorus	0.12
Manganese	0.05
Potassium	0.02
Sulfur	0.02
Oxygen	45.6
Ignition Loss	13.5

* On dry basis. Averages of two aliquots.

TABLE 3.10 AVERAGE CHANGES IN WEIGHT AND BETA ACTIVITY, RESULTING FROM WATER AND ACID WASHES

Type Of Samples	Washed With	Original Weight	Weight Loss After Wash	Change In Beta Activity*	Change In Beta Activity Concentration*
		mg	pct	pct	pct
Fallout from N-2†	Water	50.1	1.94	+ 10.9	+ 13.3
Fallout from N-2†	6N HNO_3	50.2	75.3	− 37.2	+ 154
Preshot NTS soil†	6N HNO_3	218.0	22.6	—	—

* At D + 228 days.
† 420 to 840 microns.

TABLE 3.11 WEIGHT AND ACTIVITY DISTRIBUTION OF PARTICLE TYPES IN WATER-WASHED NTS SOIL AND FALLOUT FROM STATION N-2 (420 TO 840 MICRONS)

Particle Type*	NTS Soil	Fallout		
	Contribution To Total Weight	Contribution To Total Weight	Contribution To Total Beta Activity†	Beta Activity Concentration†
	pct	pct	pct	arbitrary units
1	0	9.11	95.3	300
2	0	59.0	1.03	1
3	54.3	17.6	0.62	1
4	45.7	14.25	3.08	15

* Type 1, fused; Type 2, white and yellow opaque; Type 3, tan opaque; and Type 4, miscellaneous.
† At D+ 254 days.

The fused particles (Type 1) are the most important from the standpoint of activity, as can be seen from Table 3.11. Although they occur in several forms, they have the common feature that at least one side of every particle is a clear, glassy material with green tints. Similar particles were observed during Operation Jangle (Reference 13). The various forms are: (1) particles of one material with only one side fused; (2) particles consisting of one material that

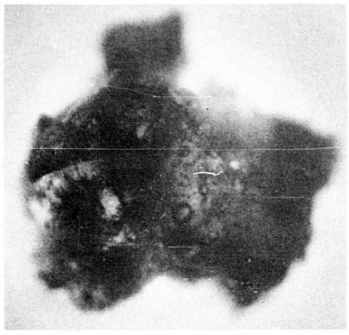


Figure 3.8 Fused fallout particle, 920 by 840 microns, magnified 62 times, photographed under transmitted light.

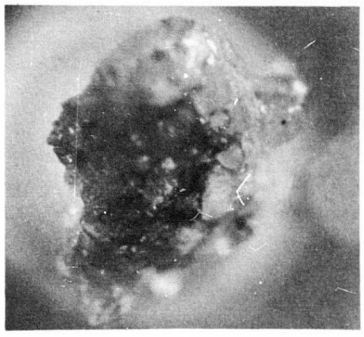


Figure 3.9 Fused fallout partucle, 880 by 1,080 microns, magnified 62 times, photographed with transmitted plus incident light.

is fused, with one or more particles of other materials impinged upon it; and (3) particles that are completely fused (all of these are very small). The fused material often contained small gas bubbles (Figures 3.8 and 3.9) and small grains of other material, usually black. Although the surfaces of the fused portions sometimes looked like bubbles or drops (Figures 3.9 and 3.10), they were more often of a flattened, convex form.

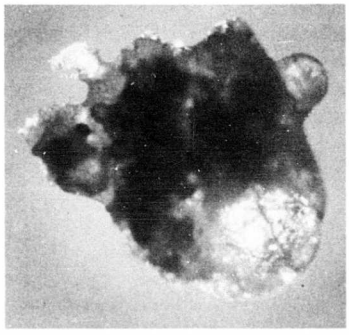


Figure 3.10 Fused fallout particle, 880 by 1,080 microns, magnified 62 times, photographed under transmitted light.

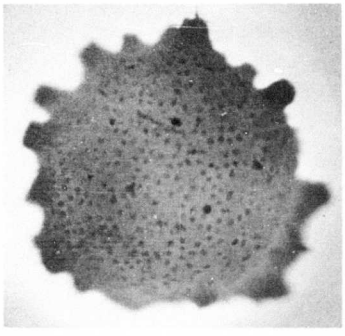


Figure 3.11 Oblate-spheroid fallout particle, 970 by 960 microns, magnified 62 times, photographed with transmitted light.

Two Type-1 particles were treated with seven successive small portions of 6N HNO_3. No change in their size or shape was observable under the microscope; however, the first washing leached off about 38 percent of the activity. Each of the remaining six washings removed only a little over 1 percent of the residual activity.

Upon treatment with concentrated HF at room temperature, the fused particles broke up into fragments. The dried fragments disintegrated into powder when they were pressed gently with a needle.

The insolubility of the fused particles in HNO_3 indicates that they were derived from the NTS soil (silicate). Their bubbly appearance suggests that they may have been heated above the boil-

ing point (2,230 C) of SiO_2 (Reference 21). The absence of fused CaO particles indicates that the fallout in this sample had not been heated above 2,570 C for an appreciable length of time.

The Type-2 particles contributed most of the weight but little of the activity of the fallout at Station N-2. There were two subclasses: (a) yellow, opaque, oblate spheroids and (b) white opaque. The surfaces of the former were covered with shiny bumps varying in size from one

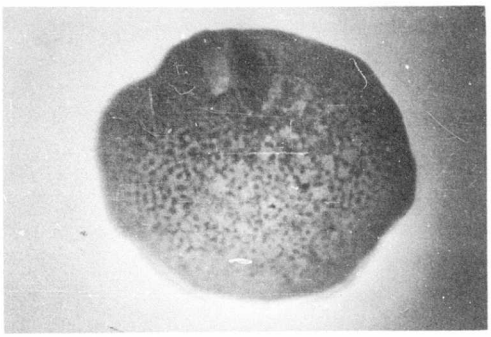


Figure 3.12 Oblate-spheroid fallout particle, 1,040 by 970 microns, magnified 62 times, photographed with transmitted light. (Dark areas are protruding farther than light areas.)

particle to another (Figures 3.11 and 3.12), and their interiors appeared to be cellular. The white opaque particles were characterized by a bright white color, and a powdery, porous surface (Figure 3.13). Similar particles were observed during Operation Redwing (Reference 15). All Type-2 particles dissolved, with vigorous bubbling, in nitric acid; therefore, they are concluded to be coral.

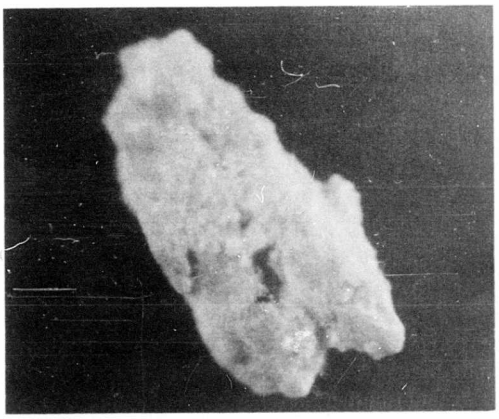


Figure 3.14 Opaque tan fallout particle, 660 by 1,320 microns, magnified 62 times, photographed with incident light.

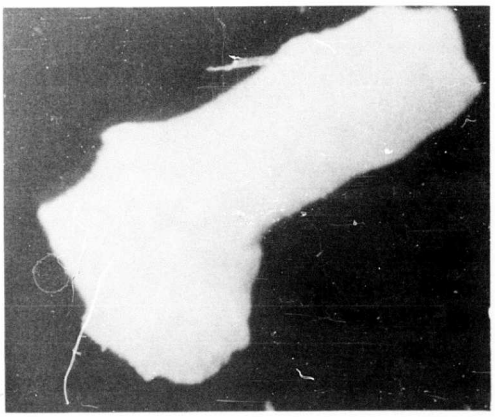


Figure 3.13 White opaque fallout particle, 1,560 by 820 microns, magnified 62 times, photographed with incident light.

The Type-3 particles had a plain, apparently firm surface (Figure 3.14). When 33 of these particles from the water-washed fallout were treated individually with HNO_3, 10 dissolved completely, 10 dissolved partially, and 13 were insoluble. When those particles that did not dissolve in HNO_3 were treated with HF at room temperature, the yellow surface material dissolved, revealing a white semicrystalline structure. After being boiled in HF, the particles retained their

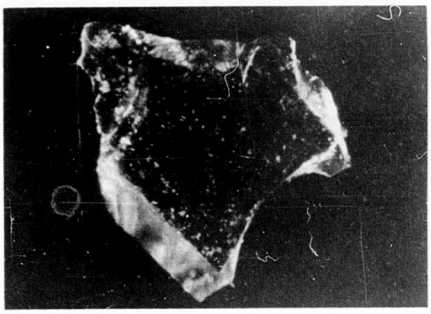


Figure 3.15 Crystalline fallout particle, 1,050 by 1,100 microns, magnified 50 times, photographed with incident light.

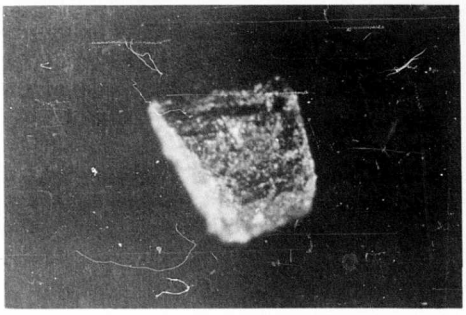


Figure 3.16 Black preshot particle, 480 by 550 microns, magnified 55 times, photographed with incident light. (Note: Particle is nonmagnetic.)

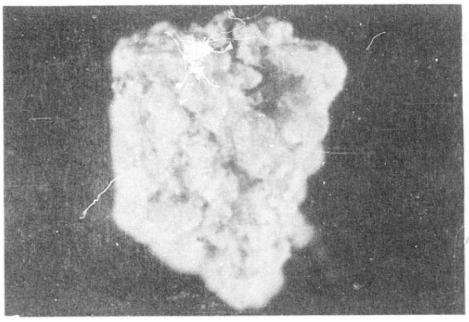


Figure 3.17 Agglomerate preshot particle, 780 by 840 microns, magnified 62 times, photographed with incident light.

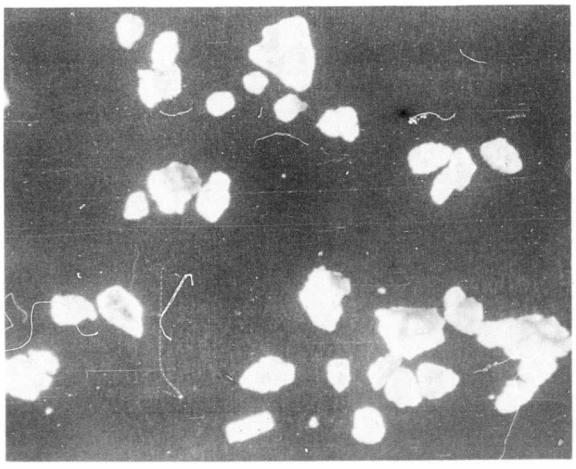


Figure 3.18 Fines from fallout fraction, less than 200 microns, magnified 62 times, photographed with incident light.

size and shape but disintegrated into a powder when pressed gently with a needle. The particles that did not dissolve in HNO_3 appeared to be five times as active as the others.

The Type-4 particles include a variety of unimportant subclasses. The crystalline particles (Figure 3.15) were colorless, insoluble in 6N HNO_3, and insoluble in boiling HF. Some of them had red or yellowish coatings which dissolved in 48-percent HF at room temperature. There were a few irregular, black particles (Figure 3.16), some of which were ferromagnetic. Contrary to results from some other shots, these particles had low activity. Agglomerates (Figure 3.17) observed in native NTS soil, both before and after washing with water and in the fallout before washing, were similar in appearance. They were not, however, observed in the water-washed fallout.

Fines, mostly smaller than 200 microns, were observed (Figure 3.18). Some of these probably resulted from the short sieving period, and the rest from the breakup of agglomerates in washing. After the water wash, the fines contributed 6.2 percent of the weight of the fallout and 8.6 percent of the preshot soil. The specific activity of the fines in the fallout was five times greater after the acid wash than after the water wash. The increase probably indicates the breaking up of some fused particles during the acid wash. A few brown, orange, gray, and bright-red particles were observed, but their activity and weight were unimportant.

Chapter 4
CONCLUSIONS and RECOMMENDATIONS

4.1 CONCLUSIONS

4.1.1 Shot Quince. For a one-point detonation of a weapon similar to the Quince device under the same environmental conditions, it would be necessary to decontaminate a 30-degree sector out to a 300-foot radius in the downwind area.

4.1.2 Shot Fig. The lip and crater, resulting from the detonation of a weapon similar to the Fig device, would have a radiation intensity above 10,000 r/hr at H+26 minutes and would have to be avoided by troops advancing at an early time. If a weapon similar to the Fig device is fired under identical conditions, the present scaling laws can be used to determine the extent of the areas contaminated to 200 r/hr. The greatest amount of fallout was collected in the downwind area along a hot line, and the quantity decreased with distance.

The fallout consisted of NTS soil and coral particles, and fractions larger than 420 microns contained most of the activity. Although there is evidence that fractionation occurred with respect to particle size, distance, and azimuth, no definite trends were observed. Several types of particles were observed. However, fused silicate particles in the 420-to-840-micron fraction were only 9 percent of the total weight, but contributed 95 percent of the total activity.

4.2 RECOMMENDATIONS

Additional very-low-yield surface shots on a larger land mass are required to determine more accurately the level and extent of fallout and the contribution of the induced activity to the resulting dose rates.

Appendix A
TABULATION of ORIGINAL DATA, CALIBRATION PROCEDURES, and SAMPLE CALCULATION

A.1 CALIBRATION PROCEDURES FOR AERIAL-SURVEY AND CRATER-SURVEY INSTRUMENTS

A high-intensity source is required to calibrate the highest scale of these instruments, 0.01 to 10 kr/hr. A 500-curie Co^{60} source, belonging to EG&G, was used. This source gave good check points from 100 mr/hr to 1,000 r/hr. Higher values were available, but accuracy was limited at distances less than 2 feet from the source by the dimensions of the chamber.

With the procedures for calibration as given by the Jordan Instrument Company literature, the instruments were adjusted at values as near the ends of the scales as possible. Readings were then taken at several known intensities, and calibration curves were drawn for each scale, plotting meter readings against known intensities. These curves were then used to correct all readings taken during actual surveys. A typical calibration curve is shown in Figure A.1.

A.2 SAMPLE CALCULATION OF ALPHA AIR CONCENTRATION

Each air sampler was calibrated to determine the amount of air pulled through in cubic feet per minute. The efficiency of the alpha counter was determined to be 75 percent. A uranium oxide standard of 3,224 counts/min was used for this purpose, as well as for the calibration of the counter. Because the whole filter paper was too large for the counter, 1-inch-square sections of it were used.

$$\text{Counter efficiency} = \frac{\text{counts of standard}}{\text{actual value of standard}} \times 100$$

$$= \frac{2{,}398 \text{ counts/min}}{3{,}224 \text{ counts/min}} \times 100 =$$

75 percent

Each square inch of filter paper counted 2.67 counts per minute. Therefore, the entire filter paper of area 15.47 in^2 would have counted:

$$\frac{2.67 \text{ counts/min}}{in^2} \times \frac{100}{75} \times 15.47 \text{ in}^2 = 55.0 \text{ counts/min}$$

$$\text{Volume of air sampled} = \text{ft}^3/\text{min} \times \text{time of sampling}$$

$$= 4.56 \text{ ft}^3/\text{min} \times 43 \text{ min} =$$

$$196 \text{ ft}^3$$

$$\text{Converting ft}^3 \text{ to m}^3 = 196 \text{ ft}^3 \times \frac{1 \text{ m}^3}{35.3 \text{ ft}^3} = 5.55 \text{ m}^3$$

Therefore, the whole filter paper counted:

$$\frac{55.0 \text{ counts/min}}{5.55 \text{ m}^3} = 9.92 \text{ (counts/min)/m}^3$$

Previous experience has shown that the shielding due to the filter paper reduced the reading by one-half; hence, a correction factor of 2 was used. The activity of the air sampled is, therefore:

$$9.92 \text{ (counts/min)/m}^3 \times 2 = 20 \text{ (dis/min)/m}^3$$

A.3 TABULATION OF ORIGINAL DATA

The tabulation is contained in Tables A.1 through A.8.

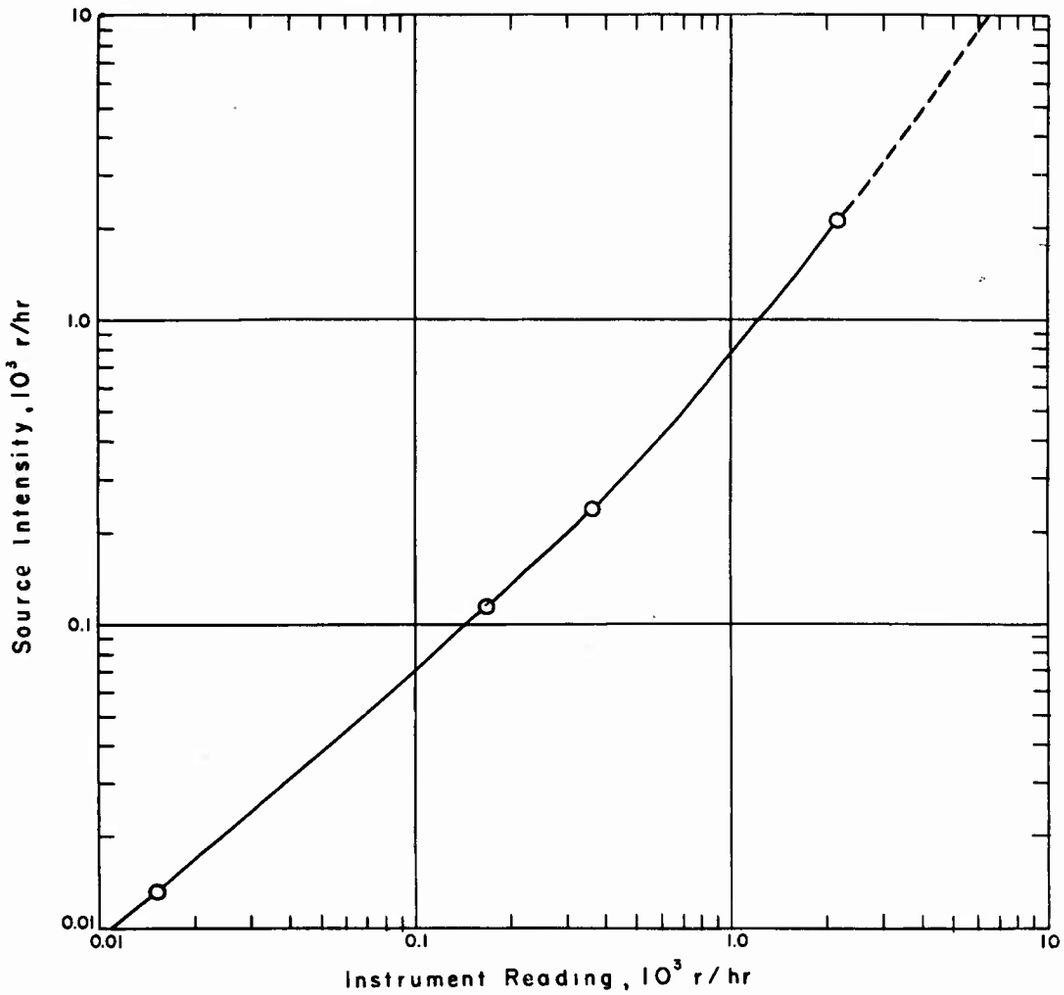


Figure A.1 Calibration curve for aerial-survey meter.

TABLE A.1 STATION LOCATIONS

Station	Equipment	Location From Ground Zero		Station	Equipment	Location From Ground Zero	
		Azimuth	Distance			Azimuth	Distance
		deg	ft			deg	ft
A'-1	Open-type collector	350	200	K-1	Open-type collector	285	200
	Alpha pad	350	200		Alpha pad	285	200
A'-2	Open-type collector	350	300	K-2	Open-type collector	285	300
	Alpha pad	—	—		Alpha pad	285	300
B'-1	Open-type collector	15	150	K-3	Open-type collector	285	400
	Alpha pad	15	150		Alpha pad	285	400
C-1	Open-type collector	60	150	L-1	Open-type collector	300	200
	Alpha pad	60	150		Alpha pad	300	200
E-1	Open-type collector	—	—	L-2	Open-type collector	300	300
	Alpha pad	120	300		Alpha pad	300	300
E'-1	Aerial-survey marker	140	300	L-3	Open-type collector	300	400
E'-2	Aerial-survey marker	140	600		Alpha pad	300	400
E'-3	Aerial-survey marker	142	900	L-4	Open-type collector	300	600
F-1	Open-type collector	150	200		Alpha pad	300	600
	Alpha pad	150	200		Open-close collector	300	600
F-2	Open-type collector	150	300	L-5	Open-type collector	300	700
	Alpha pad	150	300		Alpha pad	300	700
	Air sampler	150	300	L'-1	Aerial-survey marker	307	300
F-3	Open-type collector	150	450	L'-2	Aerial-survey marker	307	600
	Alpha pad	150	450	L'-3	Aerial-survey marker	307	900
F-4	Open-close collector	150	600	M-1	Open-type collector	315	200
	Open-type collector	150	600		Alpha pad	315	200
	Alpha pad	150	600	M-2	Open-type collector	315	300
F'-1	Aerial-survey marker	158	300		Alpha pad	315	300
F'-2	Aerial-survey marker	158	600	M-3	Open-type collector	315	400
F'-3	Aerial-survey marker	155	880		Alpha pad	315	400
X-1	Open-type collector	165	450	Z-1	Air sampler	324	300
	Alpha pad	165	450	N-1	Open-type collector	330	200
X-2	Open-type collector	165	600		Alpha pad	330	200
	Alpha pad	165	600	N-2	Open-type collector	330	300
	Open-close collector	165	600		Alpha pad	330	300
G-1	Open-type collector	180	200	N-3	Open-type collector	330	450
	Alpha pad	180	200		Alpha pad	330	450
G-2	Open-type collector	180	300	N-4	Open-type collector	330	600
	Alpha pad	180	300		Alpha pad	330	600
G-3	Open-type collector	180	400		Air sampler	330	600
	Alpha pad	180	400		Open-close collector	330	600
H-1	Open-type collector	210	200	N-5	Open-type collector	330	900
	Alpha pad	210	200		Alpha pad	330	900
H-2	Open-type collector	210	300		Aerial-survey marker	330	900
	Alpha pad	210	300	N-6	Open-type collector	330	1,200
I-1	Open-type collector	240	200		Alpha pad	330	1,200
	Alpha pad	240	200	N-7	Alpha pad	330	1,500
I-2	Open-type collector	240	300	N-1	Aerial-survey marker	336	300
	Alpha pad	240	300	N-2	Aerial-survey marker	336	600
J-1	Open-type collector	270	200	Barge (Small)	Open-type collector	258	2,100
	Alpha pad	270	200	Barge (Large)	Open-type collector (2)	270	3,600
J-2	Open-type collector	270	250	Barge (Small)	Open-type collector	263	7,600
J-3	Open-type collector	270	300	Barge (Small)	Open-type collector	270	7,600
	Alpha pad	270	300	Barge (Small)	Open-type collector	277	7,600
	Open-close collector	270	300				
	Air sampler	270	300				

SECRET

TABLE A.2 ALPHA SURVEY READINGS

Conversion factor: 420

Type of Surface Or Station	Location From Ground Zero		Time After Shot	Reading	Correction Factor	Corrected Reading	Alpha Concentration
	Azimuth	Distance					
	deg	ft	hr	counts/min		counts/min	$\mu g/m^2$
F-1, concrete pad	150	200	3/4 to 2	0	2.1	0	0
F-2, concrete pad	150	300		70		147	0.4
F-4, concrete pad	150	600		0		0	0
G-1, concrete pad	180	200		0		0	0
G-2, concrete pad	180	300		0		0	0
H-1, concrete pad	210	200		100		210	0.5
H-2, concrete pad	210	300		0		0	0
I-1, concrete pad	240	200		72,500		152,000	360
I-2, concrete pad	240	300		3,350		7,000	17
J-1, concrete pad	270	200		550		1,155	2.7
J-2, concrete pad	270	250		225		470	1.1
J-3, concrete pad	270	300		50		105	0.3
K-1, concrete pad	285	200		0		0	0
L-1, concrete pad	300	200		2,000		4,200	10
L-4, concrete pad	300	600		0		0	0
M-1, concrete pad	315	200		0		0	0
N-1, concrete pad	330	200		0		0	0
N-2, concrete pad	330	300		0		0	0
N-4, concrete pad	330	600		0		0	0
C-1, concrete pad	60	150		0		0	0
Coral	255	225		150,000	4.0	600,000	1,430
Concrete, smooth	255	275		150,000	1.5	225,000	535
Coral	255	180		210,000	4.0	840,000	2,000
Ground	255	150		350,000	4.0	1,400,000	3,300
Ground	255	120		270,000	4.0	1,080,000	2,580
Concrete, smooth	120	40		4,250	1.5	6,375	15
Concrete, smooth	120	50		1,000	1.5	1,500	3.6
Concrete, smooth	120	70		0	1.5	0	0
F-2, concrete pad	150	300	19 to 21	75	2.1	160	0.4
H-1, concrete pad	210	200		0		0	0
H-2, concrete pad	210	300		0		0	0
I-1, concrete pad	240	200		4,000		8,400	20
I-2, concrete pad	240	300		100		210	0.5
J-1, concrete pad	270	200		2,400		5,040	12
J-2, concrete pad	270	250		650		1,360	3
J-3, concrete pad	270	300		700		1,470	3.5
K-1, concrete pad	285	200		200		420	1
K-2, concrete pad	285	300		50		105	0.3
K-3, concrete pad	285	400		0		0	0
L-1, concrete pad	300	200		100		210	0.5
Plywood	240	200		50,000	1.75	87,500	208
Plywood	240	300		6,000	1.75	10,500	25
Plywood	270	200		8,000	1.75	13,600	32
Coral	270	200		4,000	4	16,000	38
Coral	255	150		$>10^5$	4	$>4 \times 10^5$	>950
Coral	255	180		$>10^5$	4	$>4 \times 10^5$	>950
Coral	255	220		$>10^5$	4	$>4 \times 10^5$	>950
Coral	255	280		$>10^5$	4	$>4 \times 10^5$	>950
Coral	255	350		$>10^5$	4	$>4 \times 10^5$	>950
Sandbag	230	90		12,000	4	48,000	114
Sandbag	230	120		10,000	4	40,000	95
Plywood	220	150		500	1.57	875	2
Concrete, smooth	120	40		4,500	1.5	6,750	16
Concrete, smooth	120	50		500	1.5	750	2
Concrete, smooth	120	70		0	1.5	0	0
J-2, concrete pad	270	250	43	300	2.1	630	1.5

TABLE A.2 CONTINUED

Conversion factor: 420

Type of Surface Or Station	Location From Ground Zero		Time After Shot	Reading	Correction Factor	Corrected Reading	Alpha Concentration
	Azimuth	Distance					
	deg	ft	hr	counts/min		counts/min	$\mu g/m^2$
J-3, concrete pad	270	300	43	200	2.1	420	1
Metal	270	300		1,000	1.0	1,000	2.4
Wood	270	300		2,000	1.5	3,000	7.2
Plywood	270	300		2,000	1.5	3,000	7.2
Plywood	270	250		5,000	1.5	7,500	18
Rain stopped further monitoring at H + 43 hours.							
H-1, concrete pad	210	200	264 to 265	0	2.1	0	0
H-2, concrete pad	210	300		0		0	0
I-1, concrete pad	240	200		500		1,050	2.5
I-2, concrete pad	240	300		50		105	0.3
J-1, concrete pad	270	200		500		1,050	2.5
J-2, concrete pad	270	250		50		105	0.3
J-3, concrete pad	270	300		0		0	0
K-1, concrete pad	285	200		0		0	0
K-2, concrete pad	285	300		0		0	0
K-3, concrete pad	285	400		0		0	0
L-1, concrete pad	300	200		150		315	0.8
Plywood	210	200		50	1.75	83	0.2
Ground	210	200		0	4	0	0
Plywood	210	300		0	1.75	0	0
Ground	210	300		0	4	0	0
Sandbag	225	90		1,200	4	4,800	11
Ground	225	90		100,000	4	4×10^5	950
Ground	225	120		300	4	1,200	3
Ground	225	150		200	4	800	2
Ground	225	200		0	4	0	0
Plywood	225	200		1,000	1.75	1,750	4
Plywood	240	200		30,000	1.75	51,000	120
Ground	240	200		0	4	0	0
Plywood	240	300		1,000	1.75	1,750	4
Ground	240	300		0	4	0	0
Ground	255	120		$>10^5$	4	$>4 \times 10^5$	>950
Ground	255	150		$>10^5$	4	$>4 \times 10^5$	>950
Ground	255	180		50,000	4	200,000	480
Ground	255	220		3,000	4	12,000	30
Ground	255	280		3,000	4	12,000	30
Ground	255	350		2,500	4	10,000	25
Plywood	270	200		9,000	1.75	15,000	36
Ground	270	200		7,000	4	28,000	67
Plywood	270	250		7,000	1.75	12,300	29
Ground	270	250		8,000	4	32,000	76
Plywood	270	300		3,000	1.75	5,250	13
Ground	270	300		600	4	2,400	6
Ground	285	100		200	4	800	2
Ground	285	150		0	4	0	0
Plywood	285	200		900	1.75	1,570	4
Ground	285	200		0	4	0	0
Plywood	285	300		250	1.75	450	1
Ground	285	300		100	4	400	1
Plywood	285	400		100	1.75	175	0.4
Ground	300	200		50	4	200	0.5
Concrete, smooth	120	40		1,500	1.5	2,250	5
Concrete, smooth	120	50		200	1.5	300	0.8
Concrete, smooth	120	70		0	1.5	0	0

TABLE A.3 GAMMA DECAY READINGS OF FALLOUT SAMPLE FROM OPEN-CLOSE COLLECTOR, STATION L-4, SHOT FIG, AND COMPOSITE DECAY AFTER NORMALIZATION

Time After Shot	Gamma Readings	Gamma Values For Composite Decay Curve After Normalization Of Samples L-4, N-2, and K-3*
hr	mr/hr	mr/hr
1.55	73.5	70
1.75	61.5	61.6
1.97	50.7†	50.7
2.18	45.6	44.6
2.75	39.7	34.9
3.00	37.7	32.7
3.25	33.7	28.8
4.00	26.7	23.5
4.5	25.7	21.4
5.0	21.7	18.6
5.5	20.8	17.5
6.0	18.8	16.08
6.5	17.8	15.05
7.0	16.8	13.85
7.5	15.7	13.12
8.0	14.7	12.3
15.5	8.3	6.43
17.58	7.6	6.28
18.5	7.1	5.9
19.9	6.6	5.43
23.25	5.2	4.33
25.0	4.8	4.01
28.75	4.0	3.42
32	3.4	2.83
41	2.5	1.77
45	1.78	1.45
48	1.1	1.14
55	0.934	0.90
65	0.57	0.58
76	0.36	0.39

* Averages of all three samples using the normalized values.
† All three decay curves normalized to this time.

TABLE A.4 GAMMA DECAY READINGS OF FALLOUT SAMPLE FROM OPEN COLLECTOR, STATION N-2, SHOT FIG

Time After Shot	Gamma Reading	Normalized To 50.7 mr/hr At H + 1.98 Hours (Factor = 0.4825)
hr	mr/hr	mr/hr
1.98	105	50.7
2.2	90	43.4
2.75	65	31.4
3.02	61.7	29.8
3.25	51.7	24.95
4.00	41.7	20.15
4.5	36.7	17.7
5	32.7	15.8
5.5	29.8	14.4
6	27.8	13.4
6.5	25.8	12.45
7	22.8	11.00
7.5	21.7	10.45
8	19.7	9.5
15.6	10.3	4.97
17.75	9.6	4.64
18.6	9.1	4.4
19.9	8.2	3.96
23.25	6.6	3.18
25	5.9	2.85
28.75	5.1	2.46
32	4.1	1.98
41	2	0.96
45	2.13	1.025
48	2.06	0.995
55	1.6	0.771
65	1.15	0.555
76	0.71	0.34

TABLE A.5 GAMMA DECAY READINGS OF FALLOUT SAMPLE FROM OPEN COLLECTOR, STATION K-3, SHOT FIG

Time After Shot	Gamma Reading	Normalized To 50.7 mr/hr At H + 1.98 Hours (Factor = 2.87)
hr	mr/hr	mr/hr
1.58	23.5	67.5
1.77	21.5	61.7
2	17.7	50.7
2.2	15.6	44.8
2.77	11.7	33.6
3.03	10.7	30.7
3.25	9.7	27.8
4.00	8.2	23.5
4.5	7.2	20.65
5.0	6.4	18.4
5.5	6.0	17.2
6.0	5.6	16.05
6.5	5.2	14.9
7.0	4.8	13.75
7.5	4.6	13.2
8	4.4	12.6
15.67	2.1	6.03
17.75	2.3	6.6
18.62	2.2	6.3
20.17	2.0	5.74
23.25	1.6	4.6
25	1.52	4.36
28.75	1.32	3.79
32	1.08	3.1
41	0.645	1.85
45	0.54	1.55
48	0.456	1.31
55	0.344	0.99
65	0.21	0.604
76	0.16	0.46

TABLE A.6 SUMMARY OF FALLOUT SAMPLES

Number	Sample In Bucket					Sample In Jars				
		Beta-Gamma Readings				Beta-Gamma Readings		Gamma Readings		
	Weight of Sample	Total Dose Rate	Time After H Hour	Weight Per Unit Area	Relative Activity Per Unit Weight	Total Dose Rate	Time After H Hour	Total Dose Rate	Time After H Hour	Gamma Relative Activity Per Unit Weight
	grams	mr/hr	hr	mg/cm²	(mr/hr)/gm	mr/hr	hr	mr/hr	hr	(mr/hr)/gm
A'-1	Not recovered									
B'-1	Not recovered - bucket blown away									
C-1	Not recovered - bucket crushed									
F-1	23.3	105	10.23	27	4.45	900	10.95	150	11.40	6.4
G-1	Not recovered - bucket overturned									
H-1	Not recovered - bucket blown away									
I-1	98.1	100	41.88	111	1.02	450	42.73	225	42.73	2.29
J-1	Not recovered									
K-1	Not recovered									
L-1	31.1	610	9.92	35	19.5	3,000	10.97	780	11.23	25
M-1	41.3	190	9.6	47	4.6	1,500	10.97	340	11.40	8.24
N-1	30.2	40	8.85	34	1.3	920	11.00	120	11.33	4
A'-2	6.4	11	10.13	7.3	1.7	130	10.88	36	11.37	5.6
E-1	4.9	25	10.33	5.6	5.05	190	11.47	70	11.47	15.7
F-2	4.0	0.5	10.62	4.5	0.125	0.07	10.83	0.01	11.42	0.0024
G-2	11.3	1.0	10.50	12.8	0.089	1.0	10.97	0.23	11.43	0.02
H-2-1	26.6	17	42.07	30	0.64	230	42.67	45	42.67	1.7
H-2-2	Not recovered - bucket crushed									
H-2-3	13.6	15	42.17	15	1.08	220	42.65	35	42.65	2.6
H-2-4	Not recovered - bucket curshed									
I-2	29.6	125	42.22	34	4.2	1,100	42.68	280	42.68	9.5
J-2	30.3	130	41.88	34	4.3	1,100	42.73	350	42.73	11.5
J-3-1	40.1	350	42.27	46	8.7	2,100	42.63	800	42.63	20
J-3-2	39.2	450	42.12	45	11.5	2,600	42.67	1,100	42.67	28
J-3-3	43.7	370	42.33	50	8.5	2,300	42.70	850	42.70	19.5
J-3-4	42.1	425	41.93	48	10	2,800	42.70	1,100	42.70	26
202.05	Collector did not open (open-close collector at Station J-3)									
K-2	4.8	260	10.43	5.5	54	2,300	10.97	410	11.38	85
L-2	6.4	0.35	9.45	7.3	0.055	700	11.03	110	11.42	17.2
M-2	10	47	10.30	11	4.7	500	10.98	92	11.38	9.2
N-2	20.9	—	—	24	—	5,000	1.47	1,100	1.47	530
G-3	6.1	2.3	10.10	6.9	0.378	20	10.92	5.9	11.35	0.965
K-3	8.0	—	—	9.09	—	5,000	1.47	1,100	1.47	140
L-3	3.0	7.3	9.08	3.4	2.43	290	10.98	42	11.22	14
M-3	4.6	6.5	9.50	5.2	1.4	70	10.98	19.9	11.37	4.1
N-3	4.3	1.8	9.30	4.9	0.42	15	11.05	1.7	11.25	0.4
F-3	1.4	0.3	10.22	1.6	0.214	1.28	11.02	0.15	11.22	1.07
X-1	3.5	0.55	9.13	4.0	0.157		10.93	3.6	11.43	1.03

TABLE A.6 CONTINUED

Number	Sample In Bucket					Sample In Jars				
		Beta-Gamma Readings				Beta-Gamma Readings		Gamma Readings		
	Weight of Sample	Total Dose Rate	Time After H Hour	Weight Per Unit Area	Relative Activity Per Unit Weight	Total Dose Rate	Time After H Hour	Total Dose Rate	Time After H Hour	Gamma Relative Activity Per Unit Weight
	grams	mr/hr	hr	mg/cm²	(mr/hr)/gm	mr/hr	hr	mr/hr	hr	(mr/hr)/gm
F-4	1.5	0.2	10.47	1.7	0.133	0.25	10.80	0.02	11.43	0.0133
202.01	No fallout collected (open-close collector at Station F-4)									
X-2-1	0.6	0	10.20	0.68	0	0.01	11.00	0.05	11.23	0.083
X-2-2	0.3	0.1	10.58	0.34	0.33	0.06	11.08	0.06	11.27	0.2
X-2-3	1.4	0	10.55	1.6	0	0.08	11.10	0.07	11.23	0.05
X-2-4	0.8	0.1	9.25	0.91	0.125	0.01	11.08	0.01	11.43	0.0125
202.02	Sample lost upon recovery (open-close collector at Station X-2)									
L-4-1	0.1	0.02	9.37	0.11	0.2	0.41	11.13	0.03	11.17	0.3
L-4-2	0.9	0.2	9.42	1.0	0.22	1.2	10.88	0.09	11.45	0.1
L-4-3	0.6	0.1	10.17	0.68	0.167	0.05	11.12	0.01	11.23	0.0167
L-4-4	0.7	0.15	9.17	0.80	0.214	0.43	11.10	0.06	11.20	0.086
202.03*	19.5	—	—	6.7	—	—	—	1,500	1.37	77
M-4	Not recovered									
N-4-1	0.6	0.13	9.58	0.68	0.215	0.26	11.07	0.11	11.27	0.183
N-4-2	0.4	0.10	9.55	0.45	0.25	0.31	11.12	0.01	11.33	0.025
N-4-3	0.4	0.13	9.65	0.45	0.325	0.1	11.07	0.06	11.23	0.15
N-4-4	0.7	0.15	9.17	0.80	0.214	0.43	11.10	0.06	11.20	0.086
202.04	No fallout collected (open-close collector at Station N-4)									
L-5	0.4	0.10	9.72	0.45	0.25	0	11.13	0.01	11.20	0.025
M-5	0.1	0.1	10.05	0.11	1.0	0	11.15	0.01	11.18	0.1
N-5	0.1	0.05	9.70	0.11	0.5	0	11.12	0.26	11.28	2.6
M-6	0.2	0	9.33	0.23	0	0	11.02	0.04	11.22	0.2
N-6	0.2	0	10.27	0.23	0	0.25	10.92	0.04	11.45	0.2
M-7	0.3	0	10.37	0.34	0	0	10.85	0.01	11.47	0.0333

* Open-close collector at Station L-4.

TABLE A.7 GAMMA GROUND-SURVEY READINGS

Station	Time of Survey After H Hour	Survey Reading (AN/PDR-39)	Survey Reading Corrected to H + 1 Hour	Average Survey Reading Corrected to H + 1 Hour
	hr	mr/hr	mr/hr	mr/hr
A'-1	19.87	600	15,600	
	23.58	380	12,300	14,000
A'-2	2.82	1,200	5,100	
	23.58	230	7,470	
	24.0	200	6,600	6,390
B'-1	19.93	1,500	39,000	39,000
C-1	19.63	1,000	25,500	
	23.58	1,000	32,500	29,000
E-1	1.75	1,800	4,140	
	3.08	1,300	6,040	
	19.63	280	7,150	
	23.28	220	7,050	
	24.0	180	5,940	
	45.88	70	7,000	6,220
F-1	1.67	7,000	15,100	
	3.08	4,600	21,400	
	19.58	800	20,400	
	23.27	600	19,600	
	45.88	220	22,000	19,700
F-2	1.67	2,000	4,300	
	3.00	1,300	5,860	
	19.58	250	6,400	
	23.76	220	7,200	
	24.0	200	6,600	
	45.88	60	6,000	6,060
F-3	3.08	440	2,030	
	19.53	80	2,040	
	23.25	75	2,400	
	45.83	21	2,100	2,140
F-4	1.58	340	680	
	2.83	210	894	
	19.53	36	918	
	23.25	27	865	
	24.0	22	725	
	45.83	10	1,000	847
X-1	2.92	430	1,870	
	23.28	80	2,560	
	45.93	22	2,200	2,210
X-2	2.83	210	894	
	19.83	26	677	
	23.30	23	736	
	45.93	8	800	777
G-1	19.92	800	20,800	
	23.32	650	20,800	
	45.94	270	27,000	22,900
G-2	3.00	1,800	8,100	
	20.00	275	7,300	
	23.32	230	7,350	
	24.0	260	8,580	
	45.94	85	8,500	7,970
G-3	1.67	1,400	3,015	
	3.00	900	4,040	
	23.30	105	3,360	
	45.94	33	3,300	3,430
H-1	1.75	14,000	32,200	
	19.97	1,600	42,500	
	19.67	1,400	36,400	
	23.33	1,500	48,000	
	46.3	480	48,000	41,400
H-2	1.75	5,000	11,500	
	19.67	420	10,900	
	23.33	370	11,800	
	24.0	300	9,900	
	46.0	120	12,000	11,200
I-1	19.67	3,600	92,000	
	21.58	2,800	80,000	
	23.35	3,100	99,200	
	46.3	1,100	110,000	95,300

TABLE A.7 CONTINUED

Station	Time of Survey After H Hour	Survey Reading (AN/PDR-39)	Survey Reading Corrected to H + 1 Hour	Average Survey Reading Corrected to H + 1 Hour
	hr	mr/hr	mr/hr	mr/hr
I-2	19.67	2,000	51,000	
	21.67	2,000	57,000	
	23.35	1,600	51,200	
	24.0	1,400	46,200	
	46.3	600	60,000	53,080
J-1	23.37	7,000	223,500	
	46.3	2,100	210,000	216,500
J-2	23.37	7,000	223,500	
	46.3	2,000	200,000	211,750
J-3	23.37	7,000	223,500	
	46.3	1,800	180,000	201,750
K-1	23.7	2,900	93,000	93,000
K-2	23.7	1,400	45,000	
	46.3	480	48,000	46,500
K-3	0.67	32,000	16,300	
	23.38	470	15,000	
	46.3	160	16,000	15,800
L-1	3.12	20,000	93,000	93,000
L-2	3.08	6,000	27,600	
	23.4	800	25,600	
	24.0	700	23,000	25,400
L-3	3.08	2,000	9,200	
	23.4	240	7,700	
	46.3	120	12,000	9,600
L-4	0.67	3,300	1,680	
	3.0	500	1,250	
	23.42	48	1,535	
	24.0	42	1,380	
	46.4	23	2,300	1,640
L-5	3.0	200	900	
	23.42	45	1,440	
	46.4	12	1,200	1,180
M-1	2.78	16,000	65,500	
	19.77	2,000	52,000	
	23.5	1,750	56,000	
	46.5	500	50,000	55,870
M-2	2.77	6,000	24,600	
	23.5	800	25,600	
	24.0	650	21,400	
	46.5	250	25,000	24,150
M-3	19.7	300	7,800	
	23.45	230	7,360	
	46.5	75	7,500	7,550
M-4	23.45	43	1,375	
	24.0	40	1,320	
	46.5	14	1,400	1,365
M-5	23.43	13	416	
	46.5	4.1	416	416
M-6	3.0	30	135	
	23.43	4.2	134	134.5
M-7	0.83	100	72	
	3.08	10	45	58.5
N-1	2.83	12,000	49,500	
	19.8	1,000	26,000	
	23.5	1,200	38,400	
	46.5	380	38,000	37,970

TABLE A.7 CONTINUED

Station	Time of Survey After H Hour	Survey Reading (AN/PDR-39)	Survey Reading Corrected to H + 1 Hour	Average Survey Reading Corrected to H + 1 Hour
	hr	mr/hr	mr/hr	mr/hr
N-2	0.58	36,000	14,400	
	19.83	800	20,800	
	23.5	480	15,350	
	24.0	340	11,200	
	46.5	130	13,000	14,950
N-3	19.97	140	3,710	
	23.5	95	3,040	
	46.5	33	3,300	3,350
N-4	0.5	3,400	1,020	
	2.92	300	1,320	
	23.52	41	1,310	
	24.0	35	1,150	
	46.5	14	1,400	1,240
N-5	2.95	50	220	
	23.52	9	288	254
N-6	2.97	24	107	
	20.05	9	238	173
A, on crater lip	46.5	8,000	832,000	832,000
A, crater lip interface	23.58	36,000	1,160,000	
	46.5	8,000	832,000	996,000
C, on crater lip	19.67	22,000	572,000	
	46.5	6,000	624,000	598,000
D, crater lip interface	23.58	25,000	805,000	805,000
E, on crater lip	46.5	6,000	624,000	624,000
E, crater lip interface	46.5	11,000	1,140,000	1,140,000
F, on crater lip	46.5	8,000	832,000	832,000
F, crater lip interface	46.5	11,000	1,140,000	1,140,000
G, on crater lip	19.67	40,000	1,040,000	
	46.5	11,000	1,140,000	1,090,000
G, crater lip interface	46.5	15,000	1,560,000	1,560,000
I, on crater lip	46.5	11,000	1,140,000	1,140,000
I, crater lip interface	46.5	15,000	1,560,000	1,560,000
G-0	23.67	2,800	90,200	
	46.5	2,700	280,000	185,100
H-0	23.67	8,000	258,000	
	46.5	2,100	218,000	238,000
I-0	23.67	6,000	193,000	
	46.5	2,000	208,000	200,000
J-0	23.67	4,500	145,000	
	46.5	2,000	208,000	166,000
K-0	23.67	2,700	86,800	
	46.5	1,200	125,000	105,900

TABLE A.8 SUMMARY OF AERIAL-SURVEY READINGS

Survey Point	Azimuth	Distance	Time After H Hour	Instrument Reading	Corrected Readings		
					Instrument	To H + 1 Hour	Average at H+1 Hour
	deg	ft	hr	mr/hr	mr/hr	mr/hr	mr/hr
C-1	60	130	23.78	40	60	1,950	1,950
E'-1	140	300	17.90	60	90	2,118	—
E'-1	140	300	24.08	21	32	1,056	1,587
E'-2	140	600	24.43	10	15	503	503
E'-3	140	900	0.33	3,000	3,000	420	—
E'-3	140	900	24.57	9	13	435	428
F-1	150	200	23.98	100	140	4,625	4,625
F-4	150	600	24.45	10	15	503	503
F'-1	159	300	17.85	50	75	1,760	—
F'-1	159	300	24.05	14	21	694	1,227
F'-2	159	600	24.40	16	24	802	802
F'-3	159	900	0.33	2,500	2,500	350	—
F'-3	159	900	24.53	9	13	436	393
I-1	240	200	24.65	300	420	14,300	—
I-1	240	200	24.67	500	700	23,800	19,050
I-2	240	300	24.63	100	150	5,100	5,100
J-1	270	200	23.88	25	37	1,220	1,220
L'-1	300	200	17.73	120	180	4,230	—
L'-1	300	200	24.17	29	43	1,424	2,827
L'-2	300	300	17.60	10	15	345	—
L'-2	300	300	24.25	12	18	596	471
L'-3	300	400	17.50	9	13	299	299
Z-1	324	300	23.92	140	200	6,600	6,600
N'-1	336	300	17.75	60	90	2,115	—
N'-1	336	300	24.18	35	52	1,720	1,918
N'-2	336	600	17.63	9	13	304	—
N'-2	336	600	24.30	15	22	728	516
N'-3	336	900	17.53	8	12	278	278
I-0	240	70	17.37	1,000	1,300	29,900	29,900
Crater area	0	50	23.95	500	700	23,100	23,100
Crater area	90	Lip	23.77	3,000	4,300	140,000	140,000
Crater area	270	Lip	17.38	3,000	4,300	99,000	99,000
Crater area	240	Lip	0.43	>10,000,000	>10,000,000	—	—

Appendix B
RADIOCHEMISTRY

B.1 SAMPLE PREPARATION

The portions of fallout samples designated for radiochemical analysis were dried at 110 C for 1 hour and accurately weighed to ± 0.1 mg. The samples were pulverized in a mortar, then treated with concentrated HF, evaporated to dryness, treated with 70-percent perchloric acid, carefully fumed almost to dryness, and treated with 6N HCl. The liquid was separated from the solid material, and the above process was repeated on the solid material. Any solid material remaining after the second treatment was discarded. The liquid solutions were combined and diluted to an appropriate volume with distilled water.

B.2 RADIOCHEMICAL SEPARATION AND COUNTING

The details of the separation procedures are essentially the same as used during Operation Redwing (Reference 15). Generally, four aliquots were taken for each analysis, and the average of the four was reported. In the analyses for Sr^{89}, Mo^{99}, Ba^{140}, and Ce^{144}, the final precipitates were mounted in the centers of $3\frac{1}{4}$-by-$2\frac{1}{2}$-by-$\frac{1}{16}$- inch aluminum plates. The Ce^{144} precipitate was evenly spread in a $\frac{1}{32}$-inch depression, $\frac{5}{16}$-inch in diameter, in the center of the aluminum plate. In the other analyses, the final precipitates were filtered through $\frac{7}{8}$-inch-diameter filter papers, which were weighed to determine chemical yield and mounted in the center of the plates. A film of rubber hydrochloride (0.45 mg/cm^2) was placed over the samples to eliminate any rearrangement of the precipitate.

All beta counting was done with thin end-window GM tubes mounted in lead pigs, Technical Associates Model AL 14A. Scalers, Atomic Instrument Company Model 1060, were used to record counts. The GM tubes were supported by the usual lucite stages, in which the distances between the tube window and the absorber shelf, Shelf 1, Shelf 2, and Shelf 3, are 0.8, 1.5, 3.1, and 4.7 cm, respectively.

Each sample (except for Sr^{89}) was counted for a total of 10,000 counts or for a total counting time of 10 minutes. Ten thousand counts provide a 95-percent probability of being within 2 percent of the actual counting rate. The 10-minute time limit was expedient because of the large volume of counting that had to be done. The Sr^{89} samples were counted for 60 minutes because of low counting rates. All samples were counted through at least one half-life, except for Ce^{144}. The samples on the aluminum cards were counted with the same orientation at all times.

The individual nuclide activities were corrected for radioactive decay (to zero time), chemical yield, self-absorption, and self-scattering. Each tube was calibrated for correction of counting rates to disintegration rates by actual measurement of a standard source for each nuclide analyzed.

The gross beta activities of the dissolved samples were measured on small aliquots of dissolved samples evaporated to dryness in glass planchets or cups. A film of rubber hydrochloride was glued over the tops of the planchets to prevent the absorption of moisture. In most cases the amount of material was small enough to eliminate significant self-absorption and self-scattering corrections.

Appendix C
INDIVIDUAL PARTICLES

C.1 LEACHING PROCEDURE

For the leaching operation, the seven 420-to-840-micron fractions of Station N-2 were placed in 15-ml-graduate centrifuge tubes. Enough distilled water was used to cover the top layer of particles, and then 1 ml of excess water was added. Each sample was shaken and tumbled by hand to insure uniform contact between particles and water, and allowed to stand for approximately 15 minutes. After centrifuging, 1 ml of liquid was removed, evaporated to dryness, and the beta activity of the residue measured. This procedure was repeated until no activity could be detected in the wash-water residue. The samples were then transferred to planchets, dried, weighed, and counted. Three of the water-washed fallout samples were then treated again, using the same procedure as above, but substituting 6N HNO_3 for the water. When the activity of the acid-wash residue was negligible, the samples were washed with water, dried, weighed, and counted.

Three preshot samples of NTS soil were treated in the same way with 6N HNO_3 except that the washing was halted when the sample weight became constant.

C.2 MICROSCOPIC EXAMINATION

Three acid-washed fallout samples, one water-washed fallout sample, one water-washed preshot sample, and one acid-washed preshot sample were selected for microscopic examination. Each sample was placed on a plastic microscope slide which had a deep groove on either side. After classification, each particle was separated from the sample by pushing it into one of the grooves with the tip of a steel needle. The particle-type portions so obtained were counted and weighed to ± 0.02 mg in aluminum foil planchets which weighed approximately 90 mg.

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